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IN the rapid progress of knowledge, we are constantly brought face to face with the question, What is Life? The answer is not yet, but a thousand earnest seekers after truth seem to be slowly approaching a solution. This question gives a new interest to every department of science that relates to life in any form, and the history of life offers a most suggestive field for research. One line of investigation lies through embryology, and here the advance is most encouraging. Another promising path leads back through the life history of the globe, and in this direction we may hope for increasing light, as a reward for patient work.

The plants and animals now living on the earth interest alike the savage and the savant, and hence have been carefully observed in every age of human history. The life of the remote past, however, is preserved only in scanty records, buried in the earth, and therefore readily escapes attention. For these reasons, the study of ancient life is one of the latest of modern sciences, and among the most difficult. In view of the great advances which this department of knowledge has made within the last decade, especially in this country, I have thought it fitting to the present occasion to review briefly its development, and have chosen for my subject this evening, THE HISTORY AND METHODS OF PALÆONTOLOGICAL DISCOVERY.

In the short time now at my command, I can only attempt to present a rapid sketch of the principal steps in the progress of this science. The literature of the subject, especially in connection with the discussions it provoked, is voluminous, and an outline of the history itself must suffice for my present purpose.

In looking over the records of Palæontology, its history may conveniently be divided into four periods, well marked by prominent features, but, like all stages of intellectual growth, without definite boundaries.

The first period, dating back to the time when men first noticed fossil remains in the rocks, and queried as to their nature, is of special historic interest. The most prominent characteristic of this period was, a long and bitter contest as to the *nature of fossil remains*. Were they mere "sports of Nature," or had they once been endowed with life? Simple as this problem now seems, centuries passed before the wise men of that time were agreed upon its solution.

Sea shells in the solid rock on the tops of mountains early attracted the attention of the ancients, and the learned men among them seem to have appreciated in some instances their true character, and given rational explanations of their presence.

The philosopher Zenophanes, of Colophon, who lived about 500 B. C., mentions the remains of fishes and other animals in the stone quarries near Syracuse; the impression of an anchovy in the rock of Paros, and various marine fossils at other places. His conclusion from these facts was, that the surface of the earth had once been in a soft condition at the bottom of the sea; and thus the objects mentioned were entombed. Herodotus, half a century later, speaks of marine shells on the hills of Egypt, and over the Libyan desert, and he inferred therefrom that the sea had once covered that whole region. Empedocles, of Agrigentum (450 B. C.), believed that the many hippopotamus bones found in Sicily were remains of human giants, in comparison with which the present race were as children. Here, he thought, was a battle field between the gods and the Titans, and the bones belonged to the slain. Pythagoras (582 B. C.) had already anticipated one conclusion of modern geology, if the following statement, attributed to him by Ovid, was his own :*

> Vidi ego quod fuerat solidissima tellus,
> Esse fretum: vidi factas ex æquore terras;
> Et procul a pelago conchæ jacuere marinæ.

* Metamorphoses, Liber XV, 262.

Aristotle (384–322 B. C.) was not only aware of the existence of fossils in the rocks, but has also placed on record sagacious views as to the changes in the earth's surface necessary to account for them. In the second book of his Meteorics, he says: "The changes of the earth are so slow in comparison to the duration of our lives, that they are overlooked; and the migrations of people after great catastrophes and their removal to other regions, cause the event to be forgotten." Again, in the same work, he says: "As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed for ever. The places where they rise were once dry, and there is a limit to their operations: but there is none to time. So of all other rivers; they spring up, and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not, some always sea, and others always continents, but everything changes in the course of time."

Aristotle's views on the subject of spontaneous generation were less sound, and his doctrines on this subject exerted a powerful influence for the succeeding twenty centuries. In the long discussion that followed concerning the nature of fossil remains, Aristotle's views were paramount. He believed that animals could originate from moist earth or the slime of rivers, and this seemed to the people of that period a much simpler way of accounting for the remains of animals in the rocks than the marvelous changes of sea and land otherwise required to explain their presence. Aristotle's opinion was in accordance with the Biblical account of the creation of Man out of the dust of the earth, and hence more readily obtained credence.

Theophrastus, a pupil of Aristotle, alludes to fossil fishes found near Heraclea, in Pontus, and in Paphlagonia, and says: "They were either developed from fish spawn left behind in the earth, or gone astray from rivers or the sea into cavities of the earth, where they had become petrified." In treating of fossil ivory and bones, the same writer supposed them to be produced by a certain plastic virtue latent in the earth. To this same cause, as we shall see, many later authors attributed the origin of all fossil remains.

Previous to this, Anaximander, the Miletian philosopher, who was born about 610 years before Christ, had expressed essentially the same view. According to both Plutarch and Censorinus, Anaximander taught that fishes, or animals very like fishes, sprang from heated water and earth, and from these animals came the human race; a statement which can hardly be considered as anticipating the modern idea of evolution, as some authors have imagined.

The Romans added but little to the knowledge possessed by the Greeks in regard to fossil remains. Pliny (23–79 A. D), however, seems to have examined such objects with interest, and in his renowned work on Natural History gave names to several forms. He doubtless borrowed largely from Theophrastus, who wrote about three hundred years before. Among the objects named by Pliny were, "*Bucardia*, like to an ox's heart;" "*Brontia*, resembling the head of a tortoise, supposed to fall in thunder storms;" "*Glossoptra*, similar to a human tongue, which does not grow in the earth, but falls from heaven while the moon is eclipsed;" "the *Horn of Ammon*, possessing, with a golden color, the figure of a ram's horn;" *Ceraunia* and *Ombria*, supposed to be thunderbolts; *Ostracites*, resembling the oyster shell; *Spongites*, having the form of sponge; *Phycites*, similar to sea-weed or rushes. He also mentions stones resembling the teeth of hippopotamus; and says that Theophrastus speaks of fossil ivory, both black and white, of bones born in the earth, and of stones bearing the figure of bones.

Tertullian (160 A. D.) mentions instances of the remains of sea animals on the mountains, far from the sea, but uses them as a proof of the general deluge recorded in Scripture.

During the next thirteen or fourteen centuries, fossil remains of animals and plants seemed to have attracted so little attention, that few references are made to them by the writers of this period. During these ages of darkness, all departments of knowledge suffered alike, and feeble repetitions of ideas derived from the ancients seem to have been about the only contributions of that period to Natural Science.

Albert the Great (1205–1280 A. D.), the most learned man of his time, mentions that a branch of a tree was found, on which was a bird's nest containing birds, the whole being solid stone. He accounted for this strange phenomenon by the *vis formativa* of Aristotle, an occult force, which, according to the prevalent notions of the time, was capable of forming most of the extraordinary objects discovered in the earth.

Alexander *ab Alexandro*, of Naples, states that he saw, in the mountains of Calabria, a considerable distance from the sea, a variegated hard marble, in which many sea shells but little changed were heaped, forming one mass with the marble.

With the beginning of the sixteenth century, a great impetus was given to the investigation of organic fossils, especially in Italy, where this study really began. The discovery of fossil shells, which abound in this region, now attracted great attention, and a fierce discussion soon arose as to the true nature of these and other remains. The ideas of Aristotle in regard to

spontaneous generation, and especially his view of the hidden forces of the earth, which he claimed had power to produce such remains, now for the first time were seriously questioned, although it was not till nearly two centuries later that these doctrines lost their dominant influence.

Leonardo da Vinci, the renowned painter and philosopher, who was born in 1452, strongly opposed the commonly accepted opinions as to the origin of organized fossils. He claimed that the fossil shells under discussion were what they seemed, and had once lived at the bottom of the sea. "You tell me," he says, "that Nature and the influence of the stars have formed these shells in the mountains; then show me a place in the mountains where the stars at the present day make shelly forms of different ages, and of different species in the same place." Again, he says, "In what manner can such a cause account for the petrifactions in the same place of various leaves, seaweeds, and marine crabs?"

In 1517, excavations in the vicinity of Verona brought to light many curious petrifactions, which led to much speculation as to their nature and origin. Among the various authors who wrote on this subject was Fracastoro, who declared that the fossils once belonged to living animals, which had lived and multiplied where found. He ridiculed the prevailing ideas that the plastic force of the ancients could fashion stones into organic forms. Some writers claimed that these shells had been left by Noah's flood, but to this idea Fracastoro offered a mass of evidence, which would now seem conclusive, but which then only aroused bitter hostility. That inundation, he said, was too transient; it consisted mainly of fresh water; and if it had transported shells to great distances, must have scattered them over the surface, not buried them in the interior of mountains.

Conrad Gesner (1516–1565), whose history of animals has been considered the basis of modern zoology, published at Zurich in 1565 a small but important work entitled "*De omni rerum fossilium genere.*" It contained a catalogue of the collection of fossils made by John Kentmann. This is the oldest catalogue of fossils with which I am acquainted.

George Agricola (1494–1555) was, according to Cuvier, the first mineralogist who appeared after the revival of learning in Europe. In his great work, "*De Re Metallica,*" published in 1546, he mentions various fossil remains, and says they were produced by a certain "*materia pinguis,*" or fatty matter, set in fermentation by heat. Some years later, Bauhin published a descriptive catalogue of the fossils he had collected in the neighborhood of Boll, in Wurtemberg.*

* *Historia novi et admirabilis Fontis Balneique Bollensis, in Ducatu Wirtembergico. Montbéliard,* 1598.

Andrew Mattioli, a distinguished botanist, adopted Agricola's notion as to the origin of organized fossils, but admitted that shells and bones might be turned into stone by being permeated by a "lapidifying juice." Falloppio, the eminent professor of anatomy at Padua, believed that fossil shells were generated by fermentation where they were found; and that the tusks of elephants, dug up near Apulia, were merely earthy concretions. Mercati, in 1574, published figures of the fossil shells preserved in the Museum of the Vatican, but expressed the opinion that they were only stones, that owed their peculiar shapes to the heavenly bodies. Olivi, of Cremona, described the fossils in the Museum at Verona, and considered them all "sports of nature."

Palissy, a French author, in 1580, opposed these views, and is said to have been the first to assert in Paris that fossil shells and fishes had once belonged to marine animals. Fabio Colonna appears to have first pointed out that some of the fossil shells found in Italy were marine, and some terrestrial.

Another peculiar theory discussed in the sixteenth century deserves mention. This was the vegetation theory, especially advocated by Tournefort and Camerarius, both eminent as botanists. These writers believed that the seeds of minerals and fossils were diffused throughout the sea and the earth, and were developed into their peculiar forms by the regular increment of their particles, similar to the formation of crystals. "How could the *Cornu Ammonis*," Tournefort asked, "which is constantly in the figure of a volute, be formed without a seed containing the same structure in the small, as in the larger forms? Who moulded it so artfully, and where are the moulds?" The stalactites which formed in caverns in various parts of the world were also supposed to be proofs of this vegetative growth.

Still another theory has been held at various times, and is not yet entirely forgotten, namely: that the Creator made fossil animals and plants just as they are found in the rocks, in pursuance of a plan beyond our comprehension. This theory has never prevailed among those familiar with scientific facts, and hence needs here no further consideration.

An interest in fossil remains arose in England later than on the continent; but when attention was directed to them, the first opinions as to their origin were not less fanciful and erroneous than those to which we have already referred. Dr. Plot, in his "Natural History of Oxfordshire," published in 1677, considered the origin of fossil shells and fishes to be due to a "plastic virtue, latent in the earth," as Theophrastus had suggested long before. Lhwyd, in his "*Lithophylacii Britannici Ichnographia*," published at Oxford in 1699, gives a cata-

logue of English fossils contained in the Ashmolean Museum. He opposed the *vis plastica* theory, and expressed the opinion that the spawn of fishes and other marine animals had been raised with the vapors from the sea, conveyed inland by clouds, and deposited by rain, had permeated into the interior of the earth, and thus produced the fossil remains we find in the rocks. About this time several important works were published in England by Dr. Martin Lister, which did much to infuse a true knowledge of fossil remains. He gave figures of recent shells side by side with some of the fossil forms, so that the resemblance became at once apparent. The fossil species of shells he called "turbinated and bivalve stones," and adds, "either these were terriginous, or, if otherwise, the animals which they so exactly represent have become extinct."

During the seventeenth century there was a considerable advance in the study of fossil remains. The discussions in regard to the nature and origin of these objects, had called attention to them, and many collections were now made, especially in Italy, and also in Germany, where a strong interest in this subject had been aroused. Catalogues of these collections were not unfrequently published, and some of them were illustrated with such accurate figures, that many of the species can now be readily recognized. In this century, too, an important step in advance was made by the collection and description of fossils from particular localities and regions, in distinction from general collections of curiosities.

Casper Schwenkfeld, in 1600, published a catalogue of the fossils discovered in Silesia; in 1622, a detailed description of the renowned Museum of Calceolarius, of Verona, appeared; and in 1642, a catalogue of Besler's collection. Wormius's catalogue was published in 1652; Spener's in 1663; and Septala's in 1666. A description of the Museum of the King of Denmark was issued in 1669; Cottorp's catalogue in 1674; and that of the renowned Kirscher in 1678. Dr. Grew gave an account in 1687 of the specimens in the Museum of Gresham's College in England; and in 1695, Petiver of London published a catalogue of his very extensive collection. A catalogue by Fred. Lauchmund, on the fossils of Hildeshein, appeared in 1669, and the fossils of Switzerland were described by John Jacob Wagner in 1689. Among similar works, were the dissertations of Gyer, at Frankfort, and Albertus, at Leipsic.

Steno, a Dane, who had been professor of anatomy at Padua, published, in 1669, one of the most important works of this period.* He entered earnestly into the controversy as to the origin of fossil remains, and by dissecting a shark from the

* *De solido intra solidum naturaliter contento.*

Mediterranean, proved that its teeth were identical with some found fossil in Tuscany. He also compared the fossil shells found in Italy with existing species, and pointed out their resemblance. In the same work, Steno expressed some very important views in regard to the different kinds of strata, and their origin, and first placed on record the important fact that the oldest rocks contain no fossils.

Scilla, the Sicilian painter, published in 1670 a work on the fossils of Calabria, well illustrated. He is very severe against those who doubted the organic origin of fossils, but is inclined to consider them relics of the Mosaic deluge.

Another instance of the power of the *lusus naturæ* theory, even at the close of the seventeenth century, deserves mention. In the year 1696, the skeleton of a fossil elephant was dug up at Tonna, near Gotha, in Germany, and was described by William Ernest Tentzel, a teacher in the Gotha Gymnasium. He declared the bones to be the remains of an animal that had lived long before. The Medical Faculty in Gotha, however, considered the subject, and decided officially that this specimen was only a freak of nature.

Beside the authors I have mentioned, there were many others who wrote about fossil remains before the close of the seventeenth century, and took part in the general discussion as to their nature and origin. During the progress of this controversy the most fantastic theories were broached and stoutly defended, and although refuted from time to time by a few clear-headed men, continually sprang up anew, in the same or modified forms. The influence of Aristotle's views of equivocal generation, and especially the scholastic tendency to disputation, so prevalent during the middle ages, had contributed largely to the retardation of progress, and yet a real advance in knowledge had been made. The long contest in regard to the nature of fossil remains was essentially over, for the more intelligent opinion at the time now acknowledged that these objects were not mere "sports of nature," but had once been endowed with life. At this point, therefore, the first period in the history of Palæontology, as I have indicated it, may appropriately end.

It is true that later still, the old exploded errors about the plastic force and fermentation were from time to time revived, as they have been almost to the present day; but learned men, with few exceptions, no longer seriously questioned that fossils were real organisms, as the ancients had once believed. The many collections of fossils that had been brought together, and the illustrated works that had been published about them, were a foundation for greater progress, and, with the eighteenth century, the second period in the history of Palæontology began.

The main characteristic of this period was the general belief, that *fossil remains were deposited by the Mosaic deluge.* We have seen that this view had already been advanced, but it was not till the beginning of the eighteenth century that it became the prevailing view. This doctrine was strongly opposed by some courageous men, and the discussion on the subject soon became even more bitter than the previous one, as to the nature of fossils.

In this diluvial discussion theologians and laymen alike took part. For nearly a century the former had it all their own way, for the general public, then as now, believed what they were taught. Noah's flood was thought to have been universal, and was the only general catastrophe of which the people of that day had any knowledge or conception.

The scholars among them were of course familiar with the accounts of Deucalion and his ark, in a previous deluge, as we are to-day with similar traditions held by various races of men. The firm belief that the earth and all it contains was created in six days; that all life on the globe was destroyed by the deluge, except alone what Noah saved; and that the earth and its inhabitants were to be destroyed by fire, was the foundation on which all knowledge of the earth was based. With such fixed opinions, the fossil remains of animals and plants were naturally regarded as relics left by the flood described in Holy Writ. The dominant nature of this belief is seen in nearly all the literature in regard to fossils published at this time, and some of the works which then appeared have become famous on this account.

In 1710, David Büttner published a volume entitled "*Rudera Diluvii Testes.*" He strongly opposed Lhwyd's explanation of the origin of fossils, and referred these objects directly to the Flood. The most renowned work, however, of this time, was published at Zurich, in 1726, by Scheuchzer, a physician and naturalist, and professor in the University of Altorf. It bore the title "*Homo Diluvii Testis.*" The specimen upon which this work was based was found at Oeningen, and was regarded as the skeleton of a child destroyed by the Deluge. The author recognized in this remarkable fossil, not merely the skeleton, but also portions of the muscles, the liver, and the brain. The same author was fortunate enough to discover, subsequently, near Altorf, two fossil vertebræ, which he at once referred to that "Accursed race destroyed by the Flood!" These, also, he carefully described and figured in his "*Physica Sacra,*" published at Ulm in 1731. Engravings of both were subsequently given in the "Copper-Bible." Cuvier afterward examined these interesting relics, and pronounced the skeleton of the supposed child to be the remains of a gigantic

Salamander, and the two vertebræ to be those of an Ichthyosaurus!

Another famous book appeared in Germany in the same year in which Scheuchzer's first volume was published. The author was John Bartholomew Adam Beringer, professor at the University of Würtzburg, and his great work* indirectly had an important influence upon the investigation of fossil remains. The history of the work is instructive, if only as an indication of the state of knowledge at that date. Professor Beringer, in accordance with views of his time, had taught his pupils that fossil remains, or "figured stones," as they were called, were mere "sports of nature." Some of his fun-loving students reasoned among themselves, "If Nature can make figured stones in sport, why cannot we?" Accordingly, from the soft limestone in the neighboring hills, they carved out figures of marvelous and fantastic forms, and buried them at the localities where the learned Professor was accustomed to dig for his fossil treasures. His delight at the discovery of these strange forms encouraged further production, and taxed the ingenuity of these youthful imitators of Nature's secret processes. At last Beringer had a large and unique collection of forms, new to him, and to science, which he determined to publish to the world. After long and patient study, his work appeared, in Latin, dedicated to the reigning prince of the country, and illustrated with twenty-one folio plates. Soon after the book was published, the deception practiced upon the credulous Professor became known; and, in place of the glory he expected from his great undertaking, he received only ridicule and disgrace. He at once endeavored to repurchase and destroy the volumes already issued, and succeeded so far that few copies of the first edition remain. His small fortune, which had been seriously impaired in bringing out his grand work, was exhausted in the effort to regain what was already issued, as the price rapidly advanced in proportion as fewer copies remained; and, mortified at the failure of his life's work, he died in poverty. It is said that some of his family, dissatisfied with the misfortune brought upon them by this disgrace and the loss of their patrimony, used a remaining copy for the production of a second edition, which met with a large sale, sufficient to repair the previous loss, and restore the family fortune. This work of Beringer, in the end, exerted an excellent influence upon the dawning science of fossil remains. Observers became more cautious in announcing supposed discoveries, and careful study of natural objects gradually replaced vague hypotheses.

* *Lithographia Wirceburgensis, ducentis lapidum figuratorum, a potiori, insectiformium, prodigiosis imaginibus exornata.* Wirceburgi, 1726. Edit. II. Francofurti et Lipsiae. 1767.

The above works, however, are hardly fair examples of the literature on fossils during this part of the eighteenth century. Scheuchzer had previously published his well-known "Complaint and Vindication of the Fishes," illustrated with good plates. Moro, in his work on "Marine Bodies which are found in the Mountains," 1740, showed the effects of volcanic action in elevating strata, and causing faults. Vallisneri had studied with care the marine deposits of Italy. Donati, in 1750, had investigated the Adriatic, and ascertained by soundings that shells and corals were being imbedded in the deposits there, just as they were found in the rocks.

John Gesner's dissertation, "*De Petrificatis*," published at Leyden in 1758, was a valuable contribution to the science. He enumerated the various kinds of fossils, and the different conditions in which they are found petrified, and stated that some of them, like those at Oeningen, resembled the shells, fishes, and plants of the neighboring region, while others, such as Ammonites and Belemnites, were either unknown species, or those found only in distant seas. He discusses the structure of the earth at length, and speculates as to the causes of changes in sea and land. He estimates that, at the observed rate of recession of the ocean, to allow the Appenines, whose summits are filled with marine shells, to reach their present height, would have taken about eighty thousand years, a period more than "ten times greater than the age of the universe." He accordingly refers the change to the direct command of the Deity, as related by Moses, that, "The waters should be gathered together in one place, and the dry land appear."

Voltaire (1694–1778), discussed geological questions and the nature of fossils in several of his works, but his published opinions are far from consistent. He ridiculed effectively and justly the cosmogonists of his day, and showed, also, that he knew the true nature of organic remains. Finding, however, that theologians used these objects to confirm the Scriptural account of the deluge, he changed his views, and accounted for fossil shells found in the Alps, by suggesting that they were Eastern species, dropped by the pilgrims on their return from the Holy Land!

Buffon, in 1749, published his important work on Natural History, and included in it his "Theory of the Earth," in which he discussed, with much ability, many points in Geology. Soon after the book was published, he received an official letter from the Faculty of Theology in Paris, stating that fourteen propositions in his works were reprehensible, and contrary to the creed of the church. The first objectionable proposition was as follows: "The waters of the sea have produced the mountains and valleys of the land,—the waters of the heavens

reducing all to a level, will at last deliver the whole land over to the sea, and the sea successively prevailing over the land, will leave dry new continents like those we inhabit."

Buffon was politely requested by the college to recant, and having no particular desire to be a martyr to science, submitted the following declaration, which he was required to publish in his next work: "I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and I abandon everything in my book respecting the formation of the earth, and, generally, all which may be contrary to the narration of Moses."

This single instance will suffice to indicate one great obstacle to the advancement of science, even up to the middle of the eighteenth century.

Another important work appeared in France about this time, Bourguet's "*Traité des Pétrifactions*," published in 1758, which is well illustrated with faithful plates. In England, a discourse on earthquakes, by Dr. Robert Hooke, was published in 1705. This author held some views in advance of his time, and maintained that figured stones were "really the several bodies they represent or the moldings of them petrified, and not, as some have imagined, a *lusus naturæ*, sporting herself in the needless formation of useless things." He anticipates one important conclusion from fossils, when he states that "though it must be very difficult to read them and to raise a chronology out of them, and to state the intervals of time wherein such or such catastrophes and mutations have happened, yet it is not impossible." He also states that fossil turtles, and such large Ammonites as are found in Portland, seem to have been the productions of hotter countries, and hence it is necessary to suppose that England once lay under the sea within the torrid zone. He seems to have suspected that some of the fossils of England belonged to extinct species, but thought they might possibly be found living in the bottom of distant oceans.

Dr. Woodward's "Natural History of the Fossils of England" appeared in 1729. This work was based on a systematic collection of fossils which he had brought together, and which he subsequently bequeathed to the University of Cambridge, where it is still preserved, with his arrangement carefully retained. This descriptive part of this work is interesting, but his conclusions are made to coincide strictly with the Scriptural account of the creation and deluge. He had previously stated, in another work, that he believed, "the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass." In support of this view, he stated that, "Marine bodies are lodged

in the strata according to the order of their gravity, the heavier shells in stones, the lighter in chalk, and so of the rest."*

The most important work on fossils published in Germany at this time, was that of George Wolfgang Knorr, which was continued after his death by Walch. This work consisted of four folio volumes, with many plates, and was printed at Nuremberg, 1755–73. A large number of fossils were accurately figured and described, and the work is one of permanent value.† A French translation of this work appeared in 1767–78. Burton's "*Oryctographie de Bruxelles*," 1784, contains figures and descriptions of fossils found in Belgium.

Abraham Gottlieb Werner (1750–1817), Professor of Mineralogy at Freyberg, did much to advance the science of Geology, and indirectly, that of fossils. He first indicated the relations of the main formations to each other, and, according to his pupil, Professor Jameson, first made the highly important observation "that different formations can be discriminated by the petrifactions they contain." Moreover, "that the petrifactions contained in the oldest rocks are very different from any of the species of the present time; that the newer the formation, the more do the remains approach in form to the organic beings of the present creation." Unfortunately, Werner published little, and his doctrines were mainly disseminated by his enthusiastic pupils.

The great contest between the Vulcanists and the Neptunists started at this time, mainly through Werner, whose doctrines led to the controversy. The comparative merits of fire and water, as agencies in the formation of certain rocks, were discussed with a heat and acrimony characteristic of the subject and the time. Werner believed in the aqueous theory, while the igneous theory was especially advocated by Hutton of Edinburgh, and his illustrator, Playfair. This discussion resulted in the advancement of descriptive geology, but the study of fossils gained little thereby.

The "*Protogæa*" of Leibnitz, the great mathematician, published in 1749, about thirty years after his death, was a work of much merit. This author supposed that the earth had gradually cooled from a state of igneous fusion, and was subsequently covered with water. The subsidence of the lower part of the earth, the deposits of sedimentary strata from inundations, and their induration, as well as other changes, followed. All this, he supposed to have been accomplished in a period of six natural days. In the same work Leibnitz shows that he had examined fossils with considerable care.

* Essay towards a Natural History of the Earth. 1695.

† *Lapides ex celeberr. viror. sententia diluvii universalis testes, quos in ordines ac species distribuit, suis coloribus expremit, etc.* 272 Tab. 1755–73.

Linnæus (1707–1778), the famous Swedish botanist, and the founder of the modern system of nomenclature in Natural History, confined his attention almost entirely to the living forms. Although he was familiar with the literature of fossil remains, and had collected them himself, he did not include them in his system of plants and animals, but kept them separate, with the minerals; hence he did little directly to advance this branch of science.

During the last quarter of the eighteenth century, the belief that fossil remains were deposited by the Deluge sensibly declined, and the dawn of a new era gradually appeared. Let us pause for a moment here, and see what real progress had been made; what foundation had been laid on which to establish a science of fossil remains.

The true nature of these objects had now been clearly determined. They were the remains of animals and plants. Most of them certainly were not the relics of the Mosaic Deluge, but had been deposited long before, part in fresh water and part in the sea. Some indicated a mild climate, and some the tropics. That any of these were extinct species, was as yet only suspected. Large collections of fossils had now been made, and valuable catalogues, well illustrated, had been published. Something was known, too, of the geological position of fossils. Steno, long before, had observed that the lowest rocks were without life. Lehmann had shown that above these primitive rocks, and derived from them, were the secondary strata, full of the records of life; and above these were alluvial deposits, which he referred to local floods, and the Deluge of Noah. Rouelle, Fuchsel, and Odoardi had shed new light on this subject. Werner had distinguished the transition rocks, containing fossil remains, between the primitive and the secondary, while everything above the chalk he grouped together, as the "overflowed land." Werner, as we have seen, had done more than this, if we give him the credit his pupils claim for him. He had found that the formations he examined contained each its own peculiar fossils, and that from the older to the newer there was a gradual approach to recent forms. William Smith had worked out the same thing in England, and should equally divide the honor of this important discovery.

The greatest advance, however, up to this time, was that men now preferred to *observe*, rather than to *believe*, and facts were held in greater esteem than vague speculations. With this preparation for future progress, the second period in the history of Palæontology, as I have divided it, may appropriately be considered at an end.

Thus far, I have said nothing in regard to one branch of my subject, the *methods* of Palæontological research, for up to

this time, of method there was none. We have seen that those of the ancients who noticed marine shells in the solid rock, called them such, and concluded that they had been left there by the sea. The discovery of fossils led directly to theories of how the earth was formed. Here the progress was slow. Subterranean spirits were supposed to guard faithfully the mysteries of the earth; while above the earth, Authority guarded with still greater power the secrets men in advance of their age sought to know. The dominant idea of the first sixteen centuries of the present era was, that the universe was made for Man. This was the great obstacle to the correct determination of the position of the earth in the universe, and, later, of the age of the earth. The contest of Astronomy against authority was long and severe, but the victory was at last with science. The contest of Geology against the same power followed, and continued almost to our day. The result is still the same. In the early stages of this contest, there was no strife, for science was benumbed by the embrace of superstition and creed, and little could be done till that was cast off. In a superstitious age, when every natural event is referred to a supernatural cause, science cannot live; and often as the sacred fire may be kindled by courageous far-seeing souls, will it be quenched by the dense mists of ignorance around it. Scarcely less fatal to the growth of science is the age of Authority, as the past proves too well. With freedom of thought, came definite knowledge, and certain progress;—but two thousand years was long to wait.

With the opening of the present century, began a new era in Palæontology, which we may here distinguish as the third period in its history. This branch of knowledge became now a science. Method replaced disorder, and systematic study superseded casual observation. For the next half century the advance was continuous, and rapid. One characteristic of this period was, *the accurate determination of fossils by comparison with living forms.* This will separate it from the two former epochs. Another distinctive feature of this period was the general belief that, *every species, recent and extinct, was a separate creation.*

At the very beginning of the epoch we are now to consider, three names stand out in bold relief: Cuvier, Lamarck, and William Smith. To these men, the science of palæontology owes its origin. Cuvier and Lamarck, in France, had all the power which great talent, education, and station could give; William Smith, an English surveyor, was without culture or influence. The last years of the eighteenth century had been spent by each of these men in preparation for his chosen

work, and the results were now given to the world. Cuvier laid the foundation of the palæontology of Vertebrate animals; Lamarck, of the Invertebrates; and Smith established the principles of Stratigraphical Palæontology. The investigator of fossils to-day seldom needs to consult earlier authors of the science.

George Cuvier (1769–1832), the most famous naturalist of his time, was led to the study of extinct animals by ascertaining that the remains of fossil elephants he examined were extinct species. "This idea," he says later, "which I announced to the Institute in the month of January 1796, opened to me views entirely new respecting the theory of the earth, and determined me to devote myself to the long researches and to the assiduous labors which have now occupied me for twenty-five years."*

It is interesting to note here that in this first investigation of fossil vertebrates, Cuvier employed the same method that gave him such important results in his later researches. Remains of elephants had been known to Europe for centuries, and many authors, from Pliny down to the contemporaries of Cuvier, had written about them. Some had regarded the bones as those of human giants, and those who recognized what they were considered them remains of the elephants imported by Hannibal or the Romans. Cuvier, however, compared the fossils directly with the bones of existing elephants, and proved them to be distinct. The fact that these remains belonged to extinct species was of great importance. In the case of fossil shells, it was difficult to say that any particular form was not living in a distant ocean; but the two species of existing elephants, the Indian and the African, were well known, and there was hardly a possibility that another living one would be found.

It is important to bear in mind, too, that Cuvier's preparation for the study of the remains of animals was far in advance of any of his predecessors. He had devoted himself for years to careful dissections in the various classes of the animal kingdom, and was really the founder of comparative anatomy, as we now understand it. Cuvier investigated the different groups of the whole kingdom with care, and proposed a new classification founded on the plan of structure, which in its main features is the one in use to-day. The first volume of his Comparative Anatomy appeared in 1800, and the work was completed in five volumes in 1805.

Previous to Cuvier, the only general catalogue of animals was contained in Linnæus' "*Systema Naturæ*." In this work, as we have seen, fossil remains were placed with the Minerals, not in their appropriate places among the animals and plants.

* *Ossemens Fossiles*, Second Edition, Vol. I, p. 178.

Cuvier enriched the animal kingdom by the introduction of fossil forms among the living, bringing all together into one comprehensive system. His great work, "*Le Règne Animal*," appeared in four volumes, in 1817, and with its two subsequent editions remains the foundation of modern zoology. Cuvier's classic work on vertebrate fossils—"*Recherches sur les Ossemens Fossiles*," in four volumes, appeared in 1812–13. Of this work, it is but just to say that it could only have been written by a man of genius, profound knowledge, the greatest industry, and with the most favorable opportunities.

The introduction to this work was the famous "Discourse on the Revolutions of the Surface of the Globe," which has perhaps been as widely read as any other scientific essay. The discovery of fossil bones in the gypsum quarries of Paris, by the workmen, who considered them human remains; the careful study of these relics by Cuvier, and his restorations from them of strange beasts that had lived long before, is a story with which you are all familiar. Cuvier was the first to prove that the earth had been inhabited by a succession of different series of animals, and he believed that those of each period were peculiar to the age in which they lived.

In looking over his work after a lapse of three-quarters of a century, we can now see that Cuvier was wrong on some important points, and failed to realize the direction in which science was rapidly tending. With all his knowledge of the earth, he could not free himself from tradition, and believed in the universality and power of the Mosaic deluge. Again, he refused to admit the evidence brought forward by his distinguished colleagues against the permanence of species, and used all his great influence to crush out the doctrine of evolution, then first proposed. Cuvier's definition of a species, the dominant one for half a century, was as follows: "A species comprehends all the individuals which descend from each other, or from a common parentage, and those which resemble them as much as they do each other."

The law of "Correlation of Structures," as laid down by Cuvier, has been more widely accepted than almost any thing else that bears his name; and yet, although founded in truth, and useful within certain limits, it would certainly lead to serious error if applied widely in the way he proposed.

In his Discourse, he sums this law as follows: "A claw, a shoulder blade, a condyle, a leg or arm bone, or any other bone separately considered, enables us to discover the description of teeth to which they have belonged; so also reciprocally we may determine the form of the other bones from the teeth. Thus, commencing our investigation by a careful survey of any one bone by itself, a person who is sufficiently master of the

laws of organic structure, may, as it were, reconstruct the whole animal to which that bone had belonged."

We know to-day that unknown extinct animals cannot be restored from a single tooth or claw, unless they are very similar to forms already known. Had Cuvier, himself, applied his methods to many forms from the early Tertiary or older formations, he would have failed. If, for instance, he had had before him the disconnected fragments of an Eocene Tillodont, he would undoubtedly have referred a molar tooth to one of his Pachyderms; an incisor tooth to a Rodent; and a claw bone to a Carnivore. The tooth of a Hesperornis would have given him no possible hint of the rest of the skeleton, nor its swimming feet the slightest clue to the ostrich-like sternum or skull. And yet, the earnest belief in his own methods led Cuvier to some of his most important discoveries.

Jean Lamarck (1744–1829), the philosopher and naturalist, a colleague of Cuvier, was a learned botanist before he became a zoologist. His researches on the invertebrate fossils of the Paris Basin, although less striking, were not less important than those of Cuvier on the vertebrates; while the conclusions he derived from them form the basis of modern biology. Lamarck's method of investigation was the same, essentially, as that used by Cuvier, namely: a direct comparison of fossils with living forms. In this way, he soon ascertained that the fossil shells imbedded in the strata beneath Paris were, many of them, extinct species, and those of different strata differed from each other. His first memoir on this subject appeared in 1802,* and, with his later works, effected a revolution in conchology. His "System of Invertebrate Animals" appeared the year before, and his famous "*Philosophie Zoologique*," in 1809. In these two works, Lamarck first announced the principles of Evolution. In the first volume of his "Natural History of Invertebrate Animals,"† he gave his theory in detail; and to-day one can only read with astonishment his far-reaching anticipations of modern science. These views were strongly supported by Geoffroy Saint-Hilaire, but bitterly opposed by Cuvier; and their great contest on this subject is well known.

In looking back from this point of view, the philosophical breadth of Lamarck's conclusions, in comparison with those of Cuvier, is clearly evident. The invertebrates on which Lamarck worked offered less striking evidence of change than the various animals investigated by Cuvier; yet they led Lamarck directly to Evolution, while Cuvier ignored what was before him on this point, and rejected the proof offered

* *Mémoires sur les fossiles des environs de Paris.* 1802–6.

† *Histoire naturelle des animaux sans vertèbres.* 7 vols. Paris, 1815–1822. 2d edition. 11 vols. 1835–1845.

by others. Both pursued the same methods, and had an abundance of material on which to work, yet the facts observed induced Cuvier to believe in catastrophes; and Lamarck, in the uniform course of nature. Cuvier declared species to be permanent; Lamarck, that they were descended from others. Both men stand in the first rank in science; but Lamarck was the prophetic genius, half a century in advance of his time.

While the Paris Basin was yielding such important results for Palæontology, its geological structure was being worked out with great care. The results appeared in a volume by Cuvier and Alex. Brongniart, chiefly the work of the latter, published in 1808.* This was the first systematic investigation of Tertiary strata. Three years later, the work was issued in a more extended form. The separate formations were here carefully distinguished by their fossils, the true importance of which for this purpose being distinctly recognized. This advance was not accepted without some opposition, and it is an interesting fact that Jameson, who claimed for Werner the theory here put in practice, rejected its application, and wrote as follows: "To Cuvier and Brongniart we are indebted for much valuable information in their description of the country around Paris, but we must protest against the use they have made of fossil organic remains in their geognostical descriptions and investigations."†

William Smith (1769–1839), "the father of English Geology," had previously published a "Tabular View of the British Strata." He appears to have arrived independently at essentially the same view as Werner in regard to the relative position of stratified rocks. He had determined that the order of succession was constant, and that the different formations might be identified at distant points by the fossils they contained. In his later works, "Strata identified by Organized Fossils," published in 1816–20, and "Stratigraphical System of Organized Fossils," 1817, he gave to the world results of many years of careful investigations on the Secondary formations of England. In the latter work, he speaks of the success of his method in determining strata by their fossils, as follows: "My original method of tracing the strata by the organized fossils imbedded therein, is thus reduced to a science not difficult to learn. Ever since the first written account of this discovery was circulated in 1799, it has been closely investigated by my scientific acquaintances in the vicinity of Bath, some of whom search the quarries of different Strata in that district, with as much cer-

* *Essai sur la Géographie Mineralogique des environs de Paris.* 4to, 1808.
† Translation of Cuvier's Discourse. Note K. (B.), p. 103, 1817.

tainty of finding the characteristic Fossils of the respective rocks, as if they were on the shelves of their cabinets."

The systematic study of fossils now attracted attention in England, also, and was prosecuted with considerable zeal, although with less important results than in France. An extensive work on this subject, by James Parkinson, entitled "Organic Remains of a Former World," was begun in 1804, and completed in three volumes in 1811. A second edition appeared in 1833. This work was far in advance of previous publications in England, and, being well illustrated, did much to make the collection and study of fossils popular. The belief in the geological effects of the Deluge had not yet lost its power, although restricted now to the later deposits; for Parkinson in his later edition wrote as follows: "Why the earth was at first so constituted that the deluge should be rendered necessary—why the earth could not have been at first stored with all those substances, and endued with all those properties which seemed to have proceeded from the deluge—why so many beings were created, as it appears, for the purpose of being destroyed — are questions which I presume not to answer."

William Buckland (1784–1856), published in 1823 his celebrated "*Reliquiæ Diluvianæ*," in which he gave the results of his own observations in regard to the animal remains found in the caves, fissures and alluvial gravels of England. The facts presented are of great value, and the work was long a model for similar researches. Buckland's conclusions were, that none of the human remains discovered in the caves were as old as the extinct mammals found with them, and that the Deluge was universal. In speaking of fossil bones found in the Himalaya mountains, he says: "The occurrence of these bones at such an enormous elevation in the region of eternal snow, and consequently in a spot now unfrequented by such animals as the horse and deer, can, I think, be explained only by supposing them to be of antediluvian origin, and that the carcasses of the animals were drifted to their present place, and lodged in sand, by the diluvial waters."

The foundation of the "Geological Society of London," in 1807, marks an important point in the history of palæontology. To carefully collect materials for future generalizations, was the object in view, and this organization gradually became the centre in Great Britain for those interested in geological science. The society was incorporated in 1826, and has since been the leading organization in Europe for the advancement of the sciences within its field. The Geological Society of France, established at Paris in 1832, and the German Geological Society, founded at Berlin in 1848, have likewise contributed largely to geological investigations in these countries, and

to some extent in other parts of the world. In the publications of these three societies, the student of palæontology will find a mine of valuable materials for his work.

The systematic study of fossil Plants may be said to date from the publication of Adolphe Brongniart's "*Prodrome*," in 1828.* This was very soon followed by his larger work, "*Histoire des végétaux fossiles*," issued in 1828–48. Brongniart pursued the same method as Cuvier and Lamarck, viz: the comparison of fossils with living forms, and his results were of great importance. In his "*Tableau des genres végétaux fossiles*," etc., published in Paris in 1849, he gives the classification and distribution of the genera of fossil plants, and traces out the historical progression of vegetable life on the globe, as he had done to a great extent in his previous works. He shows that the cryptogamic forms prevailed in the primary formations; the conifers and cycads in the secondary, and the higher forms in the Tertiary, while four fifths of living plants are exogens.

In England, Lindley and Hutton published, in 1831–37, a valuable work in three volumes, entitled, "Fossil Flora of Great Britain." This work was illustrated by many accurate plates, in which the plants of the coal formation were especially represented. Henry Witham also published two works in 1831 and 1833, in which he treated especially of the internal structure of fossil plants. "Antediluvian Phytology," by Artis, was published in London in 1838. Bowerbank's "History of the Fossil Fruits and Seeds of the London Clay," appeared in 1843. Hooker's memoir "On the Vegetation of the Carboniferous Period as compared with that of the present day," published in 1848, was an important contribution to the science. Bunbury, Williamson, and others, also published various papers on fossil plants. This branch of Palæontology, however, attracted much less attention in England, than on the Continent.

In Germany, the study of fossil plants dates back to the beginning of the century. Von Schlotheim, a pupil of Werner, published in 1804 an illustrated volume on this subject. A more important work was that of Count Sternberg, issued in 1820–38, and illustrated with excellent plates. Cotta in 1832 published a book with the title, "*Die Dendrolithen*," in which he gave the results of his investigations on the inner structure of fossil plants. Von Gutbier in 1835, and Germar in 1844–53, described and figured the plants of two important localities in Germany. Corda's "*Beiträge zur Flora der Vorwelt*," issued at Prague, in 1845, was essentially a continu-

* *Prodrome d'une histoire des végétaux fossiles.* 8vo. Paris, 1828.

ation of the work of Sternberg. Unger's "*Chloris protogæa*," 1841–45, "*Genera et species plantarum fossilium*," 1850, and his larger work published in 1852, are all standard authorities. In the latter, the theory of descent is applied to the vegetable world. Schimper and Mougeot's "Monograph on the fossil plants of the Vosges," 1845, was well illustrated, and contained noteworthy results.

Göppert, in 1836, published a valuable memoir entitled, "*Systema Filicum Fossilium*," in which he made known the results of his study of fossil ferns. In the same year, this botanist began a series of experiments, in which he attempted to imitate the process of fossilization, as found in nature. He steeped various animal and vegetable substances in waters holding, some calcareous, others siliceous, and others metallic matter in solution. After a slow saturation, the substances were dried, and exposed to heat until the organic matters were burned. In this way Göppert successfully imitated various processes of petrifaction, and explained many things in regard to fossils that had previously been in question. His discovery of the remains of plants throughout the interior of coal did much to clear up the doubts about the formation of that substance. In 1841, Göppert published an important work in which he compared the genera of fossil plants with those now living. In 1852, another extensive work by this author appeared, entitled, "*Fossile Flora des Uebergangs-Gebirges.*"

Andræ, Braun, Dunker, Ettinsghausen, Geinitz, and Goldenberg, all made notable contributions to fossil Botany in Germany, during the period we are now considering.

The systematic study of invertebrate fossils, so admirably begun by Lamarck, was continued actively in France. The Tertiary shells of the Seine valley were further investigated by Defrance, and especially by Deshayes, whose great work on this subject was begun in 1824.* DesMoulin's essay on *Sphérulites* in 1826, Blainville's memoir on *Belemnites* in 1827, Férussac's various memoirs on land and fresh water fossil shells, were valuable additions to the subject. A later work of great importance was D'Orbigny's *Paléontologie Française*, 1840–44, which described the mollusca and radiates in detail, according to formations. The other publications of this author are both numerous and valuable. Brongniart and Desmarest's "*Histoire naturelle des Crustacés Fossiles*," published in 1822, is a pioneer work on this subject. Michelins' memoir on the fossil corals of France, 1841–46, was another important contribution to palæontology. Agassiz's works on fossil Echinoderms and Mollusks are valuable contributions to the science. The

* *Description des coquilles fossiles des environs de Paris.* 3 vols. Paris, 1824–37.

works of d'Archiac, Coquand, Cotteau, Desor, Edwards, Haime, and De Verneuil, are likewise of permanent value.

In Italy, Bellardi, Merian, Michellotti, Phillipi, Zigno, and others, contributed important results to Palæontology.

In Belgium, Bosquet, Nyst, Koninck, Ryckholt, Van Beneden, and others, have all aided materially in the progress of the science.

In England, also, invertebrate fossils were studied with care, and continued progress was made. Sowerby's "Mineral Conchology of Great Britain," in six volumes, a systematic work of great value, was published in 1812–30, and soon after was translated into French and German. Its figures of fossil shells are excellent, and it is still a standard work. Miller's "Natural History of the Crinoidea," published at Bristol, in 1821, and Austin's later monograph, are valuable for reference. Brown's "Fossil Conchology of Britain and Ireland" appeared in 1839, and Brodie's History of the Fossil Insects of England, in 1845. Phillips' illustration of the geology of Yorkshire, 1829–36, and his work on the Palæozoic fossils of Cornwall, Devonshire, and West Somerset, 1843, contained a great deal of original matter in regard to fossil remains. Morris' "Catalogue of British Fossils," issued in 1843, and the later edition in 1854, is most useful to the working palæontologist. The memoirs of Davidson on the Brachiopoda, Edwards, Forbes, Morris, Lycett, Sharpe, and Wood on other Mollusca, Wright on the Echinoderms, Salter on Crustacea, Busk on Polyzoa, Jones on the Entomostraca, and Duncan and Lonsdale on Corals, are of especial value. King's volume on Permian fossils, Mantell's various memoirs, Dixon's work on the fossils of Sussex, 1850, and McCoy's works on Palæozoic fossils, all deserve honorable mention. Sedgwick, Murchison, and Lyell, although their greatest services were in systematic geology, each contributed important results to the kindred science of palæontology during the period we are reviewing.

In Germany, Schlotheim's treatise, "*Die Petrifactenkunde*," published at Gotha in 1820, did much to promote a general interest in fossils. By far the most important work issued on this subject was the "*Petrifacta Germanica*," by Goldfuss, in three folio volumes, 1826 to 1844, which has lost little of its value. Bronn's "*Geschichte der Natur*," 1841–46, was a work of great labor, and one of the most useful in the literature of this period. The author gave a list of all the known fossil species, with full references, and also their distribution through the various formations. This gave exact data on which to base generalizations, hitherto of comparatively little value.

Among other early works of interest in this department may be mentioned, Dalman's memoir on *Trilobites*, 1828, and Bur-

meister's on the same subject, 1843. Giebel's well known "*Fauna der Vorwelt*," 1847–1856, gave lists of all the fossils described up to that time, and hence is a very useful work. The "*Lethæa Geognostica*" by Bronn, 1834–38, and the second edition by Bronn and Roemer, 1846–56, is a comprehensive general treatise on Palæontology, and the most valuable work of the kind yet published.

The researches of Ehrenberg, in regard to the lowest forms of animals and plants, threw much light on various points in Palæontology, and showed the origin of extensive deposits, the nature of which had before been in doubt. Von Buch, Barrande, Beyrich, Berendt, Dunker, Geinitz, Heer, Hörnes, Klipstein, Von Münster, Reuss, Roemer, Sandberger, Suess, Von Hagenow, Von Hauer, Zeiten, and many others, all aided in the advancement of this branch of science. Angelin, Hisinger, and Nilsson, in Scandinavia; Abich, DeWaldheim, Eichwald, Keyserling, Kutorga, Nordmann, Pander, Rouillier, and Volborth, in Russia; and Pusch in Poland, published important results on fossil invertebrates.

The impetus given by Cuvier to the study of vertebrate fossils extended over Europe, and great efforts were made to continue discoveries in the direction he had so admirably pointed out.

Louis Agassiz (1807–73), a pupil of Cuvier, and long an honored member of this association, attained eminence in the study of ancient as well as of recent life. His great work on Fossil Fishes* deserves to rank next to Cuvier's "*Ossemens Fossiles.*" The latter contained mainly fossil mammals and reptiles, while the fishes were left without a historian till Agassiz began his investigations. His studies had admirably fitted him for the task, and his industry brought together a vast array of facts bearing on the subject. The value of this grand work consists not only in its faithful descriptions and plates, but also in the more profound results it contained. Agassiz first showed that there is a correspondence between the succession of fishes in the rocks, and their embryonal development. This is now thought to be one of the strongest points in favor of evolution, although its discoverer interpreted the facts as bearing the other way.

Pander's memoirs on the fossil fishes of Russia form a worthy supplement to Agassiz's classic work. Brandt's publications are likewise of great value; and those of Lund, in Sweden, have an especial interest to Americans, in consequence of his researches in the caves of Brazil.

Croizet and Jobert's "*Recherches sur les ossemens fossiles du département du Puy-de-Dôme*," published in 1828, contained

* *Recherches sur les Poissons fossiles*, 1833–45.

valuable results in regard to fossil mammals. Geoffroy St. Hilaire's researches on fossil Reptiles, published in 1831, were an important advance. De Serres and De Christol's explorations in the caverns in the South of France, published between 1829 and 1839, were of much value. Schmerling's researches in the caverns of Belgium, published in 1833–36, were especially important on account of the discovery of human remains mingled with those of extinct animals. Deslongchamp's memoirs on fossil reptiles, 1835, are still of great interest. Pictet's general treatise on palæontology was a valuable addition to the literature, and has done much to encourage the study of fossils.* DeBlainville, in his grand work, "*Ostéographie*," issued in 1839–56, brought together the remains of living and extinct vertebrates, forming a series of the greatest value for study. Aymard and Pomel's contributions to vertebrate Palæontology are both of value. Gervais and Lartet added much to our knowledge of the subject, and Bravard and Hébert's memoirs are well known.

The brilliant discoveries of Cuvier in the Paris Basin, excited great interest in England, and when it was found that the same Tertiary strata existed in the south of England, careful search was made for vertebrate fossils. Remains of some of the same genera described by Cuvier were soon discovered, and other extinct animals new to science were found in various parts of the kingdom. König, to whom we owe the name *Ichthyosaurus*, and Conybeare, who gave the generic designation *Plesiosaurus*, and also *Mosasaurus*, were among the earliest writers in England on fossil reptiles. The discovery of these three extinct types, and the discussion as to their nature, forms a most interesting chapter in the annals of Palæontology. The discovery of the *Iguanodon*, by Mantell, and the *Megalosaurus*, by Buckland, excited still higher interest. These great reptiles differed much more widely from living forms than the mammals described by Cuvier, and the period in which they lived soon became known as the "age of Reptiles." The subsequent researches of these authors added largely to the existing knowledge of various extinct forms, and their writings did much to arouse public interest in the subject.

Richard Owen, a pupil of Cuvier, followed, and brought to bear upon the subject an extensive knowledge of comparative anatomy, and a wide acquaintance with existing forms. His contributions have enriched almost every department of palæontology, and of extinct vertebrates especially, he has been, since Cuvier, the chief historian. The fossil reptiles of

* "*Traité élémentaire de paléontologie*," etc., *Genève.* 4 vols. 1844–46. Second Edition. Paris, 1853–55.

England, he has systematically described, as well as those of South Africa. The extinct Struthious birds of New Zealand, he has made known to science, and accurately described in extended memoirs. His researches on the fossil mammals of Great Britain, the extinct Edentates of South America, and the ancient Marsupials of Australia, each forms an important chapter in the history of our science.

The personal researches of Falconer and Cautley in the Sewalik Hills of India brought to light a marvelous vertebrate fauna of Pliocene age. The remains thus secured were made known in their great work, "*Fauna Antiqua Sivalensis*," published at London in 1845. The important contributions of Egerton to our knowledge of fossil fishes, and Jardine's well known work, "Ichnology of Annandale," also belong to this period.

The study of vertebrate fossils in Germany was prosecuted with much success during the present period. Blumenbach, the ethnologist, in several publications between 1803 and 1814, recorded valuable observations on this subject. In 1812, Sömmerring gave an excellent figure of a pterodactyle, which he named and described. Goldfuss' researches on the fossil vertebrates from the Caves of Germany, published in 1820–23, made known the more important facts of that interesting fauna. His later publications on extinct Amphibians and Reptiles were also noteworthy. Jäger's investigations on the extinct vertebrate fauna of Wurtemberg, published between 1824 and 1839, were an important advance. To Plieninger's researches in the same region, 1834–44, we owe the discovery of the first Triassic mammal (*Microlestes*), as well as important information in regard to Labyrinthodonts. Kaup's researches on fossil mammals, 1832–41, brought to light many interesting forms, and to him we are indebted for the generic name *Dinotherium*, and excellent descriptions of the remains then known.

Count Münster's "*Beiträge zur Petrifacten-Kunde*," published 1843–46, contained several valuable papers on fossil vertebrates; and the separate papers by the same author are of interest. Andreas Wagner wrote on Pterosaurians in 1837, and later gave the first description of fossil mammals of the Tertiary of Greece, 1837–40. Johannes Müller published an important illustrated work on the Zeuglodonts, in 1849, and various notable memoirs; and Quenstedt, interesting descriptions of fossil reptiles, as well as other papers of much value. Rütimeyer's suggestive memoirs are widely known.

Hermann von Meyer's contributions to vertebrate palæontology are by far the most important published in Germany during the period we are now considering. From 1830, his

investigations on this subject were continuous for nearly forty years, and his various publications are all of value. His "*Beiträge zur Petrifactenkunde*," 1831–33, contains a series of valuable memoirs. His "*Palæologica*," issued in 1832, includes a synopsis of the fossil vertebrates then known, with much original matter. His great work, "*Zur Fauna der Vorwelt*," 1845–60, includes a series of monographs invaluable to the student of vertebrate palæontology. This work, as well as his other chief publications, was illustrated with admirable plates from his own drawings. Other memoirs by this author will be found in the "*Palæontographica*," of which he was one of the editors. In the many volumes of this publication, which began in 1851, and is still continued, will be found much to interest the investigator in any branch of palæontology.

The "Palæontographical Society of London," established in 1847, has also issued a series of volumes containing valuable memoirs in various branches of Palæontology. These two publications together are a storehouse of knowledge in regard to extinct forms of animal and vegetable life.

It may be interesting here to note briefly the use of general terms in Palæontology, as the gradual progress of the science was indicated to some extent in its terminology. At first, and for a long time, the name "*fossil*" was appropriately used for objects dug from the earth, both minerals and organic remains. The term "Oryctology," having essentially the same meaning, was also used for this branch of study. For a long period, too, the termination *ites* (λίθος, a stone) was applied to fossils to distinguish them from the corresponding living forms; as, for instance, "*Ostracites*," used by Pliny. At a later date, the general name "figured stones" (*lapides figurati*) was extensively used; and less frequently, "Deluge stones" (*lapides diluviani*). The term "organized fossils" was used to distinguish fossils from minerals, when the real difference became known, although the name "*Reliquiæ*" was sometimes employed. The term "petrifactions" (*Petrificata*) was defined by John Gesner in his work on fossils in 1758, and was afterwards extensively used. Palæontology is comparatively a modern term, having come into use only within the last half century. It was introduced about 1830, and soon was generally adopted in France and England; but in Germany it met with less favor, though used to some extent.

It would be interesting, too, did time permit, to trace the various opinions and superstitions, held at different times, in regard to some of the more common fossils, for example, the Ammonite, or the Belemnite. Of their supposed celestial

origin; of their use as medicine by the ancients, and in the East to-day; of their marvellous power as charms, among the Romans, and still among the American Indians. It would be instructive, also, to compare the various views expressed by students in science, concerning some of the stranger extinct forms, for instance, the Nummulites, among Protozoa; the Rudistes, among Mollusks; or the Mosasaurus, among Reptiles. Dissimilar as such views were, they indicate in many cases gropings after truth,—natural steps in the increase of knowledge.

The third period in the history of Palæontology, which, as I have said, began with Cuvier and Lamarck at the beginning of the present century, forms a natural epoch extending through six decades. The definite characteristics of this period, as stated, were dominant during all this time, and the progress of Palæontology was commensurate with that of intelligence and culture.

For the first half of this period, the marvelous discoveries in the Paris Basin excited astonishment, and absorbed attention; but the real significance and value of the facts made known by Cuvier, Lamarck, and William Smith, were not appreciated. There was still a strong tendency to regard fossils merely as interesting objects of natural history, as in the previous period, and not as the key to profounder problems in the earth's history. Many prominent geologists were still endeavoring to identify formations in different countries by their mineral characters, rather than by the fossils imbedded in them. Such names as "Old Red Sandstone," and "New Red Sandstone," were given in accordance with this opinion. Humboldt, for example, attempted to compare the formations of South America and Europe by their mineral features, and doubted the value of fossils for this purpose. In 1823, he wrote as follows: "Are we justified in concluding that all formations are characterized by particular species? that the fossil shells of the chalk, the muschelkalk, the Jura limestone, and the Alpine limestones, are all different? I think this would be pushing the induction much too far."* Jameson still thought minerals more important than fossils for characterizing formations; while Bakewell, later yet, defines Palæontology as comprising "Fossil Zoology and Fossil Botany, a knowledge of which may appear to the student as having little connection with Geology."

During the later half of the third period, greater progress was made, and before its close Geology was thoroughly established as a science. Let us consider for a moment what had really been accomplished up to this time.

It had now been proved beyond question that portions at least of the Earth's surface had been covered many times by

* *Essai géognostique sur le gisement des Roches*, p. 41.

the sea, with alternations of fresh water and of land; that the strata thus deposited were formed in succession, the lowest of the series being the oldest; that a distinct succession of animals and plants had inhabited the earth during the different geological periods; and that the order of succession found in one part of the earth was essentially the same in all. More than 30,000 new species of extinct animals and plants had now been described. It had been found, too, that from the oldest formations to the most recent, there had been an advance in the grade of life, both animal and vegetable, the oldest forms being among the simplest, and the higher forms successively making their appearance.

It had now become clearly evident, moreover, that the fossils from the older formations were all extinct species, and that only in the most recent deposits were there remains of forms still living. The equally important fact had been established, that in several groups of both animals and plants, the extinct forms were vastly more numerous than the living; while several orders of fossil animals had no representatives in modern times. Human remains had been found mingled with those of extinct animals, but the association was regarded as an accidental one by the authorities in science; and the very recent appearance of Man on the earth was not seriously questioned. Another important conclusion reached, mainly through the labors of Lyell, was, that the earth had not been subjected in the past to sudden and violent revolutions; but the great changes wrought had been gradual, differing in no essential respect from those still in progress. Strangely enough, the corollary to this proposition, that Life, too, had been continuous on the earth, formed at that date no part of the common stock of knowledge.

In the physical world, the great law of "Correlation of forces" had been announced, and widely accepted; but in the organic world, the dogma of the miraculous creation of each separate species still held sway, almost as completely as when Linnæus declared: "There are as many different species as there were different forms created in the beginning by the Infinite Being." But the dawn of a new era was already breaking, and the third period of palæontology we may consider now at an end.

Just twenty years ago, science had reached a point when the belief in "special creations" was undermined by well established facts, slowly accumulated. The time was ripe. Many naturalists were working at the problem, convinced that Evolution was the key to the present and the past. But how had Nature brought this change about? While others pondered, Darwin spoke the magic word—"*Natural Selection*," and a new epoch in science began.

The fourth period in the history of Palæontology dates from this time, and is the period of to-day. One of the main characteristics of this epoch is the belief that *all life, living and extinct, has been evolved from simple forms.* Another prominent feature is the accepted fact of *the great antiquity of the human race.* These are quite sufficient to distinguish this period sharply from those that preceded it.

The publication of Charles Darwin's work on the "Origin of Species," November, 1859, at once aroused attention, and started a revolution which has already in the short space of two decades changed the whole course of scientific thought. The theory of "Natural Selection," or as Spencer has happily termed it, the "Survival of the Fittest," had been worked out independently by Wallace, who justly shares the honor of the discovery. We have seen that the theory of Evolution was proposed and advocated by Lamarck, but he was before his time. The anonymous author of the "Vestiges of Creation," which appeared in 1844, advocated a somewhat similar theory which attracted much attention, but the belief that species were immutable was not sensibly affected until Darwin's work appeared.

The difference between Lamarck and Darwin is essentially this: Lamarck proposed the theory of Evolution; Darwin changed this into a doctrine, which is now guiding the investigations in all departments of biology. Lamarck failed to realize the importance of time, and the interaction of life on life. Darwin, by combining these influences with those also suggested by Lamarck, has shown *how* the existing forms on the earth may have been derived from those of the past.

This revolution has influenced Palæontology as extensively as any other department of science, and hence the new period we are discussing. In the last epoch, species were represented independently, by parallel lines; in the present period, they are indicated by dependent, branching lines. The former was the analytic, the latter is the synthetic, period. To-day, the animals and plants now living are believed to be genetically connected with those of the distant past; and the palæontologist no longer deems species of the first importance, but seeks for relationships and genealogies, connecting the past with the present. Working in this spirit, and with such a method, the advance during the last decade has been great, and is an earnest of what is yet to come.

The progress of Palæontology in Great Britain during the present period has been great, and the general interest in the science much extended. The views of Darwin soon found acceptance here. Next to his discovery of "Natural Selection,"

Darwin was fortunate in having so able and bold an expounder as Huxley; who was one of the first to adopt his theory, and give it a vigorous support. Huxley's masterly researches have been of great benefit to all departments of Biology, and his contributions to Palæontology are invaluable. Among the latter, his original investigations on the relations of Birds and Reptiles are especially noteworthy. His various memoirs on extinct Reptiles, Amphibians and Fishes, belong to the permanent literature of the subject. The important researches of Owen on the fossil vertebrates have been continued to the present time. He has added largely to his previous publications on the British fossil Reptiles, Birds, and Mammals; the extinct reptiles of South Africa, and the Post-Tertiary birds of New Zealand. His description of the *Archæopteryx* near the beginning of the period was a most welcome contribution.

The investigations of Egerton on Fossil Fishes have likewise been continued with important results. Busk, Dawkins, Flower and Sanford have made valuable contributions to the history of fossil Mammals. Bell, Günther, Hulke, Lankester, Powrie, Miall, and Seely, have made notable additions to our knowledge of Reptiles, Amphibians, and Fishes. Among Invertebrates, the Crustacea have been especially studied by Jones, Salter, and Woodward. Davidson, Etheridge, Lycett, Morris, Phillips, Wood, and Wright have continued their researches on the Mollusks; Duncan, Nicholson and others have investigated the extinct Corals; and Binney, Carruthers, and Williamson, the Fossil Plants. Numerous other important contributions have been made to the science in Great Britain during the present period.

On the Continent, the advance in Palæontology has, during the last two decades, been equally great. In France, Gervais continued his memoirs on extinct vertebrates nearly to the present date; while Gaudry has published several volumes on the subject that are models for all students of the science. His work on the fossil animals of Greece is a perfect monograph of its kind, and his later publications are all of importance. Lartet's various works are of permanent value, and his application of Palæontology to Archæology brought notable results. The volume of Alphonse Milne-Edwards on fossil Crustacea was a fit supplement to Brongniart and Desmarest's well known work; while his grand memoir on fossil Birds deserves to rank with the classic volumes of Cuvier. Duvernoy, Filhol, Hébert, Sauvage and others have also published interesting results on fossil vertebrates.

Van Beneden's researches on the fossil vertebrates of Belgium have produced results of great value. Pictet, Rütimeyer, and Wedersheim in Switzerland, Bianconi, Forsyth-Major, and

Sismonda in Italy, and Nodot in Spain, have likewise published important memoirs. The extinct vertebrates have been studied in Germany by Von Meyer, Carus, Fraas, Giebel, Haeckel, Haase, Hensel, Kayser, Kner, Ludwig, Peters, Portis, Maack, Salenka, Zittel, and many others; in Holland by Winkler, in Denmark by Reinhardt; and in Russia by Brandt and Kowalewsky.

The fossil invertebrates have been investigated with care by D'Archiac, D'Orbigny, Bayle, Fromentel, Oustalet, and others in France; Desor, Loriol and Roux in Switzerland; Cappellini, Massalongo, Michellotti, Meneghini, and Sismonda in Italy, Barrande, Benecke, Beyrich, Dames, Dorn, Ehlers, Geinitz, Giebel, Gümbel, Feistmantel, Hagen, von Hauer, von Heyden, von Fritsch, Laube, Oppel, Quenstedt, Roemer, Schlüter, Suess, Speyer, and Zittel in Germany. The fossil Plants have been studied in these countries by Massalongo, Saporta, Zigno, Fiedler, Goldenberg, Gehler, Heer, Goeppert, Ludwig, Schimper, Schenk, and many others.

Among the recent researches in Palæontology in other regions may be mentioned those of Blanford, Feistmantel, Lydekker, and Stoliczka, in India; Haast and Hector in New Zealand, and Krefft and McCoy in Australia; all of whom have published valuable results.

Of the progress of palæontology in America, I have thus far said nothing, and I need now say but little, as many of you are doubtless familiar with its main features. During the first and second periods in the history of palæontology, as I have defined them, America, for most excellent reasons, took no part. In the present century, during the third period, appear the names of Bigsby, Green, Morton, Mitchell, Rafinesque, Say, and Troost, all of whom deserve mention. More recently, the researches of Conrad, Dana, Deane, DeKay, Emmons, Gibbes, Hitchcock, Holmes, Lea, McChesney, Owen, Redfield, Rogers, Shumard, Swallow, and many others, have enlarged our knowledge of the fossils of this country.

The contributions of James Hall to the Invertebrate Palæontology of this country form the basis of our present knowledge of the subject. The extensive labors of Meek in the same department are likewise entitled to great credit, and will form an important chapter in the history of the science. The memoirs of Billings, Gabb, Scudder, White, and Whitfield are numerous and important; and the publications of Derby, Hartt, James, Miller, Shaler, Rathburn, and Winchell, are also of value. To Dawson, Lesquereux, and Newberry, we mainly owe our present knowledge of the fossil plants of this country.

The foundation of our vertebrate Palæontology was laid by Leidy, whose contributions have enriched nearly every department of the subject. The numerous publications of Cope are well known. Agassiz, Allen, Baird, Dawson, Deane, DeKay, Emmons, Gibbes, Harlan, Hitchcock, Jefferson, Lea, LeConte, Newberry, Redfield, St. John, Warren, Whitney, Worthen, Wyman, and others, have all added to our knowledge of American fossil vertebrates. The chief results in this department of our subject, I have already laid before you on a previous occasion, and hence need not dwell upon them here.

In this rapid sketch of the history of Palæontology, I have thought it best to speak of the earlier periods more in detail, as they are less generally known, and especially as they indicate the growth of the science, and the obstacles it had to surmount. With the present work in palæontology, moreover, you are all more or less familiar, as the results are now part of the current literature. To assign every important discovery to its author, would have led me far beyond my present plan. I have only endeavored to indicate the growth of the science by citing the more prominent works that mark its progress, or illustrate the prevailing opinions and state of knowledge at the time they were written.

In considering what has been accomplished, directly or indirectly, it is well to bear in mind that without palæontology there would have been no science of geology. The latter science originated from the study of fossils, and not the reverse, as generally supposed. Palæontology, therefore, is not a mere branch of geology, but the foundation on which that science mainly rests. This fact is a sufficient excuse, if one were wanting, for noting the early opinions in regard to the changes of the earth's surface, as these changes were first studied to explain the position of fossils. The investigation of the latter first led to theories of the earth's formation, and thus to geology. When speculation replaced observation, fossils were discarded, and for a time the mineral characters of strata were thought to be the key to their position and age. For some time after this, geologists, as we have seen, apologized for using fossils to determine formations, but for the last half century their value for this purpose has been fully recognized.

The services which Palæontology has rendered to Botany and Zoology are less easy to estimate, but are very extensive. The classification of these sciences has been rendered much more complete by the intercalation of many intermediate forms. The probable origin of various living species has been indicated by the genealogies suggested by extinct types; while our knowledge of the geographical distribution of animals and

plants at the present day has been greatly improved by the facts brought out in regard to the former distribution of life on the globe.

Among the vast number of new species which have been added are the representatives of a number of new orders entirely unknown among living forms. The distribution of these extinct orders, among the different classes, is interesting, as they are mainly confined to the higher groups. Among the fossil Plants, no new orders have yet been found. There are none known among the Protozoa, or the Mollusca. The Radiates have been enriched by the extinct orders of Blastoidea, Cystidea, and Edrioasterida; and the Crustaceans by the Eurypterida and Trilobita. Among the Vertebrates, no extinct order of fossil Fishes has yet been found; but the Amphibians have been enlarged by the important order Labyrinthodonta. The greatest additions have been among the Reptiles, where the majority of the orders are extinct. Here we have at the present date the Ichthyosauria, Sauranodontia, Plesiosauria and Mosasauria, among the marine forms; the Pterosauria, including the Pteranodontia, containing the flying forms; and the Dinosauria, including the Sauropoda—the giants among reptiles; likewise the Dicynodontia, and probably the Theriodontia, among the terrestrial forms. Although but few fossil Birds have been found below the Tertiary, we have already among the Mesozoic forms three new orders: the Saururæ, represented by *Archæopteryx;* the Odontotormæ, with *Ichthyornis* as the type; and the Odontolcæ, based upon *Hesperornis;* all of these orders being included in the sub-class Odontornithes, or toothed birds. Among Mammals, the new groups regarded as orders are the Toxodontia, and the Dinocerata, among the Ungulates; and the Tillodontia, including strange Eocene Mammals whose exact affinities are yet to be determined.

Among the important results in vertebrate palæontology, are the genealogies, made out with considerable probability, for various existing animals. Many of the larger mammals have been traced back through allied forms in a closely connected series to early Tertiary times. In several cases the series are so complete that there can be little doubt that the line of descent has been established. The Evolution of the horse, for example, is to-day demonstrated by the specimens now known. The demonstration in one case stands for all. The evidence in favor of the genealogy of the horse now rests on the same foundation as the proof that any fossil bone once formed part of the skeleton of a living animal. A special creation of a single bone is as probable as the special creation of a single species. The method of the palæontologist in the investigation

of the one, is the method for the other. The only choice lies between natural derivation and supernatural creation.

For such reasons it is now regarded among the active workers in science as a waste of time to discuss the truth of Evolution. The battle on this point has been fought, and won.

The geographical distribution of animals and plants, as well as their migrations, has received much new light from Palæontology. The fossils found in some natural divisions of the earth are related so closely to the forms now living there, that a genetic connection between them can hardly be doubted. The extinct Marsupials of Australia, and the Edentates of South America, are well known examples. The Pliocene hippopotami of Asia and the South of Europe point directly to migrations from Africa. Other similar examples are numerous. The fossil plants of the Arctic region prove the existence of a climate there far milder than at present, and recent researches at least render more probable the suggestion, made long ago by Buffon, in his "Epochs of Nature," that life began in the polar regions, and by successive migrations from them the continents were peopled.

The great services which Comparative Anatomy rendered to Palæontology at the hands of Cuvier, Agassiz, Owen, and others, have been amply repaid. The solution of some of the most difficult problems in Anatomy has received scarcely less aid from the extinct forms discovered, than from Embryology; and the two lines of research supplement each other. Our present knowledge of the vertebrate skull, the limb-arches, and the limbs, has been much enlarged by researches in Palæontology. On the other hand, the recent labors of Gegenbaur, Huxley, Parker, Balfour, and Thacher, will make clear many obscure points in ancient Life.

One of the important results of recent palæontological research, is the law of brain-growth, found to exist among extinct mammals, and to some extent in other vertebrates. According to this law, as I have briefly stated it elsewhere: "All Tertiary mammals had small brains. There was, also, a gradual increase in the size of the brain during this period. This increase was confined mainly to the cerebral hemispheres, or higher portions of the brain. In some groups, the convolutions of the brain have gradually become more complicated. In some, the cerebellum and the olfactory lobes have even diminished in size." More recent researches render it probable that the same general law of brain-growth holds good for birds and reptiles from the Mesozoic to the present time. The Cre-

taceous birds, that have been investigated with reference to this point, had brains only about one-third as large in proportion as those nearest allied among living species. The Dinosaurs from our Western Jurassic follow the same law, and had brain cavities vastly smaller than any existing reptiles. Many other facts point in the same direction, and indicate that the general law will hold good for all extinct vertebrates.

Palæontology has rendered great service to the more recent science of Archæology. At the beginning of the present period, a re-examination of the evidence in regard to the antiquity of the human race was going on, and important results were soon attained. Evidence in favor of the presence of man on the earth at a period far earlier than the accepted chronology of six thousand years would imply, had been gradually accumulating; but had been rejected from time to time by the highest authorities. In 1823, Cuvier, Brongniart, and Buckland, and later, Lyell, refused to admit that human relics, and the bones of extinct animals found with them, were of the same geological age, although experienced geologists, such as Boué and others, had been convinced by collecting them. Christol, Serres, and Tournal, in France, and Schmerling in Belgium, had found human remains in caves, associated closely with those of various extinct mammals, and other similar facts were on record.

Boucher de Perthes, in 1841, began to collect stone implements in the gravels of the valley of the Somme, and, in 1847, published the first volume of his "*Antiquités Celtiques.*" In this work, he described the specimens he had found, and asserted their great antiquity. The facts as presented, however, were not generally accepted. Twelve years later, Falconer, Evans, and Prestwich examined the same localities with care, became convinced, and the results were published in 1859 and 1860. About the same time Gaudry, Hébert, and Desnoyers, also explored the same valley, and announced that the stone implements there were as ancient as the mammoth and rhinoceros found with them. Explorations in the Swiss lakes and in the Danish shell heaps added new testimony bearing in the same direction. In 1863, appeared Lyell's work on the "Geological Evidences of the Antiquity of Man," in which facts were brought together from various parts of the world, proving beyond question the great age of the human race.

The additional proof since brought to light has been extensive, and is still rapidly increasing. The Quaternary age of man is now generally accepted. Attempts have recently been made to approximate in years the time of man's first appearance on the earth. One high authority has estimated the antiquity of man merely to the last glacial epoch of Europe as

250,000 years; and those best qualified to judge, would, I think, regard this as a fair estimate.

Important evidence has likewise been adduced of man's existence in the Tertiary, both in Europe and America. The evidence to-day is in favor of the presence of man in the Pliocene of this country. The proof offered on this point by Professor J. D. Whitney, in his recent work,* is so strong, and his careful, conscientious method of investigation so well known, that his conclusions seem irresistible. Whether the Pliocene strata he has explored so fully on the Pacific coast corresponds strictly with the deposits which bear this name in Europe, may be a question requiring further consideration. At present, the known facts indicate that the American beds containing human remains, and works of man, are as old as the Pliocene of Europe. The existence of Man in the Tertiary period seems now fairly established.

In looking back over the history of Palæontology, much seems to have been accomplished; and yet the work has but just begun. A small fraction only of the earth's surface has been examined, and two large continents are waiting to be explored. The "imperfection of the geological record," so often cited by friends and foes, still remains, although much improved; but the future is full of promise. In filling out this record, America, I believe, will do her full share, and thus aid in the solution of the great problems now before us.

I have endeavored to define clearly the different periods in the history of Palæontology. If I may venture, in conclusion, to characterize the present period in all departments of science, its main feature would be a *belief in universal laws.* The reign of Law, first recognized in the physical world, has now been extended to Life, as well. In return, Life has given to inanimate nature the key to her profounder mysteries—Evolution, which embraces the universe.

What is to be the main characteristic of the next period? No one now can tell. But if we are permitted to continue in imagination the rapidly converging lines of research pursued to-day, they seem to meet at the point where organic and inorganic nature become one. That this point will yet be reached, I cannot doubt.

* Auriferous Gravels of the Sierra Nevada of California. 1879.

Art. XLII.—*On the Diamagnetic Constants of Bismuth and Calc-spar in Absolute Measure.*

Part I.—By H. A. Rowland, Professor of Physics in the Johns Hopkins University.

Since my experiments on the magnetic constants of iron, nickel and cobalt, I have sought the means of determining those of some diamagnetic substances, and to that end have described a method in this Journal for May, 1875, (vol. ix, page 357). As Mr. Jacques, Fellow of the University, was willing to take up the experimental portion, I have here worked up the subject more in detail and brought the formulæ into practical shape. No experiments have been made on this subject so far, but some rough comparisons with iron have been made by Becquerel, Plucker and Weber. But as iron varies so greatly, and as the methods of experiment are inexact, we cannot be said to know much about the subject. As, however, the relative results of these experiments and those of Faraday can be accepted as reasonably exact for diamagnetic substances and weak paramagnetic ones, it is only necessary to make a determination of one substance such as bismuth, and then the rest can be readily found. But as bismuth is very crystalline it is necessary to make our formulæ general, unless we use bismuth in a powder, which would introduce error.

The general method of experiment has been indicated in the paper before referred to, but I may here state that it consists in counting the number of vibrations made by a bar hung in the usual manner between the poles of an electromagnet. The distribution of the magnetic force in the field being known, we can then calculate the force acting on the body, and the comparison of this with the time of vibration gives us the means of determining the constant sought. But I will leave the more exact description to be given by Mr. Jacques in the experimental part.

Exploration of field.

The first operation to be performed is to find a formula to express the force of the field at any point, and an experimental means of determining it in absolute measure. The magnet used was one on the method of Ruhmkorff, and hence the field was nearly symmetrical around the axis of the two branches, and also with respect to a plane perpendicular to the axis at a point midway between its poles. Should any want of symmetry exist by accident, it will be nearly neutralized in its effect on the final result, seeing that the diamagnetic bar hangs symmetrically.

The proper expansion of the magnetic potential for this case is therefore a series of zonal spherical harmonies, including only the uneven powers. Hence, if V is the potential,

$$(1) \qquad V = A_{,} Q_{,} r + A_{,,,} Q_{,,,} r^{3} + A_{v} Q_{v} r^{5} + \text{ etc.}$$

where r is the distance from the center of symmetry, $Q_{,}$, $Q_{,,,}$ etc., are the spherical harmonies with respect to the angle between r and the axis, and $A_{,}$, $A_{,,,}$ A_{v}, etc., are constants to be found by experiment. The only method known of measuring a strong magnetic field with accuracy is by means of induced currents, and in this case I have used a modification of the method of the proof plane as I have described it in this Journal, III, vol. x, p. 14. In the method there described the coil was to be drawn rapidly away from the given point: in the present case the coil was moved along the axis, thus measuring the difference of the field at several points; on then placing it at the center and drawing it away, the field was measured at that point. The field at the other points along this axis could then be found by adding the measured difference to this quantity. This method is far more accurate than the direct measurement at the different points.

When a wire is moved in a magnetic field the current induced in it is equal to the change of its potential energy, supposing it to transmit a unit current, divided by the resistance of the circuit. The potential energy of a wire in a magnetic field is (Maxwell's Elec., Art. 410),

$$P = \int \left(l \frac{dV}{dx} + m \frac{dV}{dy} + n \frac{dV}{dz} \right) dS$$

which is simply the surface integral of V over any surface whose edge is in the wire.

In the present case, take the axis of x in the direction of the axis of the poles and the surface, S, parallel to the plane YZ, and let ρ be the distance in this plane from the center of the coil we are calculating. Then

$$P = 2\pi \int \frac{dV}{dx} \rho d\rho = \pi \int \frac{dV}{dx} d(\rho^{2})$$

for a single circle.

From (1) $$\frac{dV}{dx} = \Sigma_{\infty}^{0} (i+1) A_{i+1} r^{i} Q_{i}$$

and $$\rho^{2} = x^{2} \left(\frac{1}{\mu^{2}} - 1 \right); \quad r^{i} = \frac{x^{i}}{\mu^{i}}$$

where $\mu = \cos \theta$

$$\therefore P = -2\pi x^{i+2} \Sigma (i+1) A_{i+1} \int_{1}^{\mu} \frac{Q_{i} d\mu}{\mu^{i+3}}$$

$$P = 2\pi \rho^{2} \Sigma_{\infty}^{0} A_{i+1} \frac{r^{i} Q_{i+1}}{i+2}$$

For a circle of rectangular section we must obtain the mean value of this quantity throughout the section of the coil.

$$\therefore \mathrm{M} = \frac{1}{\eta\xi}\int_{x_0-\frac{1}{2}\eta}^{x_0+\frac{1}{2}\eta}\int_{\rho_0-\frac{1}{2}\xi}^{\rho_0+\frac{1}{2}\xi} \mathrm{P}\,dx\,d\rho$$

Where x_0 and ρ_0 are the values of x and ρ at the center of section and η and ξ are the width and depth of the groove in which the coil is wound. We can calculate this quantity best by the formula of Maxwell (Electricity, Art. 700),

$$\mathrm{M} = \mathrm{P}_0 + \tfrac{1}{24}\left(\frac{d^2p_0}{d\rho^2}\xi^2 + \frac{d^2p_0}{dx^2}\eta^2\right) + \text{etc.}$$

Thus we finally find

$$(2)\quad \mathrm{M} = \pi\rho^2\Big\{\mathrm{A}_1\left(1+\tfrac{1}{16}\frac{\xi^2}{\rho^2}\right)+\tfrac{1}{2}\mathrm{A}_{111}r^2_0\left(\mathrm{Q}^1_{111}+\tfrac{1}{2}(5\mu^2-3)\frac{\xi^2}{\rho^2}+\tfrac{1}{2}\frac{\eta^2}{\rho^2}(1-\mu^2)\right)$$
$$+\tfrac{1}{8}\mathrm{A}_V\mathrm{Q}^1_V r^4_0 + \text{etc.}\Big\}$$

It is by aid of this equation that we find the coefficients A_1, A_{111}, etc. in the expansion of the magnetic potential, V. For, let the coil be moved in the field from a position where M has the value M′ to where it has the value M″: then if the coil be joined to a galvanometer the current induced will be equal to

$$\frac{\mathrm{M}'-\mathrm{M}''}{\mathrm{R}}$$

where R is the resistance of the circuit. If an earth inductor is included in the circuit whose integral area is E, when it is reversed the current is $\frac{2\mathrm{HE}}{\mathrm{R}}$ where H is the component of the earth's magnetism perpendicular to the plane of the inductor. The current as measured by the galvanometer in the first case will be $\mathrm{C}\sin\frac{1}{2}\delta\,(1+\frac{1}{2}\lambda)$ and in the second $\mathrm{C}\sin\frac{1}{2}\mathrm{D}\,(1+\frac{1}{2}\lambda)$, where C is the constant of the galvanometer and λ is the logarithmic decrement.

Hence

$$\frac{\mathrm{M}'-\mathrm{M}''}{\mathrm{R}} = \mathrm{C}\sin\tfrac{1}{2}\delta\,(1+\tfrac{1}{2}\lambda)$$

$$\frac{2\mathrm{HE}}{\mathrm{R}} = \mathrm{C}\sin\tfrac{1}{2}\mathrm{D}\,(1+\tfrac{1}{2}\lambda)$$

$$\therefore \mathrm{M}'-\mathrm{M}'' = 2\mathrm{HE}\frac{\sin\frac{1}{2}\delta}{\sin\frac{1}{2}\mathrm{D}}$$

In this way we can obtain a series of equations containing A_1, A_{111}, etc., and can thus find these by elimination.

This completes the exploration, and we have as a result a formula giving the magnetic potential of the field in absolute measure throughout a certain small region in which we can experiment.

The next process is to consider the action of this field upon any body which we may hang in it.

Crystalline Body in Magnetic Field.

Let the body have such feeble magnetic action that the magnetic field is not very much influenced by its presence. In all crystalline substances we know there exist in general three axes at right angles to each other, along which the magnetic induction is in the direction of the magnetic force. Let k_1, k_2 and k_3 be the coefficients of magnetization in the directions of these axes and let a set of coördinate axes be drawn parallel to these crystalline axes, the coördinates referred to which are designated by x', y' and z', and the magnetic components of the force parallel to which are X′, Y′ and Z′.

The energy of the crystalline body will then be

$$E = -\tfrac{1}{2}\iiint (k_1 X'^2 + k_2 Y'^2 + k_3 Z'^2)\, dx'dy'dz'$$

In most cases it is more convenient to refer the equation to axes in some other direction through the crystal. Let these axes be X, Y, Z.

Then

$$\begin{aligned} x &= x'\alpha + y'\beta + z'\gamma \\ y &= x'\alpha' + y'\beta' + z'\gamma' \\ z &= x'\alpha'' + y'\beta'' + z'\gamma'' \end{aligned}$$

$$X' = \frac{dV}{dx'} = \frac{dV}{dx}\alpha + \frac{dV}{dy}\alpha' + \frac{dV}{dy}\alpha''$$

$$Y' = \text{etc.}$$

Hence

$$\begin{aligned} X' &= X\alpha + Y\alpha' + Z\alpha'' \\ Y' &= X\beta + Y\beta' + Z\beta'' \\ Z' &= X\gamma + Y\gamma' + Z\gamma'' \end{aligned}$$

where α, β, γ; α', β', γ'; and α'', β'', γ'' are the direction cosines of the new axes with reference to the old.

We then find

$$\begin{aligned} E = -\tfrac{1}{2}\iiint \{ & X^2(k_1\alpha^2 + k_2\beta^2 + k_3\gamma^2) + Y^2(k_1\alpha'^2 + k_2\beta'^2 + k_3\gamma'^2) \\ & + Z^2(k_1\alpha''^2 + k_2\beta''^2 + k_3\gamma''^2) + 2XY(k_1\alpha\alpha' + k_2\beta\beta' + k_3\gamma\gamma') + 2XZ \\ & (k_1\alpha\alpha' + k^2\beta\beta'' + k_3\gamma\gamma'') + 2YZ(k_1\alpha\,\alpha'' + k_2\beta'\beta'' + k_3\gamma'\gamma'') \}\, dx\,dy\,dz \end{aligned}$$

The most simple and in many respects the most interesting cases are when the crystal has only one optic or magnetic axis. In this case $k_2 = k_3$.

Hence

$$E = -\tfrac{1}{2}\iiint \{(X^2 + Y^2 + Z^2)k_2 + (X\alpha + Y\alpha' + Z\alpha'')^2(k_1 - k_2)\}\, dx\,dy\,dz$$

where α, α' and α'' are the direction cosines of the magnetic axis with respect to the coördinate axes.

The first case to consider is that of a mass of crystal in a uniform magnetic field. The magnetic forces which enter the equation are those due to the magnetic action of the body as well as to the field in which the body is placed. In the case of very weak magnetic or diamagnetic bodies the forces are almost entirely those of the field alone. Hence in the case under consideration we may put $Y=0$ and $Z=0$.

Hence

$$E = -\tfrac{1}{2} \iiint X^2 \left((k_1 - k_2)\, \alpha^2 + k_2 \right) dx\, dy\, dz,$$

and if v is the volume of the body

$$E = -\tfrac{1}{2} X^2 \left((k - k_2)\, \alpha^2 + k_2 \right) v$$

As this expression is the same at all points of the field there is no force acting to translate the body from one part of the field to another. The moment of the force tending to increase φ, where $\varphi = \cos^{-1} a$, is

$$-\frac{dE}{d\varphi} = v\, X^2\, (k_1 - k_2) \sin \varphi \cos \varphi$$

By observing the moment of the force which acts on a crystal placed in a uniform magnetic field we can thus find the value of $k_1 - k_2$ or the difference of the magnetic constant along the axis and at right angles to it. The differences of the constants can also be found in the case of crystals with three axes by a similar process.

The next case which I shall consider is that of a bar hanging in a magnetic field. Let the field be symmetrical around an horizontal axis, and also with reference to a plane perpendicular to that axis at the center. If the bar is very long with reference to its section and a plane can be passed through it and the axis we must have $Z=0$, and the equation becomes

$$E = -\tfrac{1}{2} \iiint \left\{ (X^2 + Y^2)\, k_2 + (X\alpha + Y\alpha')^2\, (k_1 - k_2) \right\} dx\, dy\, dz$$

Let the axis of X coincide with the long axis of the bar, as this will in the end lead to the most simple result, seeing that we have to integrate along the length of the bar.

Let r be the length along the bar from the center to any point, and let θ be the angle made by the bar with the axis of symmetry: then

$$X = -\frac{dV}{dr} \qquad Y = -\frac{1}{r}\frac{dV}{d\theta}$$

also let the section of the bar be

$$a = dy\, dz$$

and let the axis of the bar pass through the origin from which we have developed the potential in terms of spherical harmonies. We can then write as before

$$V = A_1 Q_1 r + A_{111} Q_{111} r^3 + A_V Q_V r^5 + \text{etc.}$$

where $Q_{,}$ $Q_{,,,}$ etc. are zonal spherical harmonies with reference to the angle θ,

$$X = -\{A_{,}Q_{,} + 3A_{,,,}Q_{,,,}r^{2} + 5A_{v}Q_{v}r^{4} + \text{etc.}\}$$
$$Y = +\{A_{,}Q^{1}_{,} + A_{,,,}Q^{1}_{,,,}r^{2} + A_{v}Q'_{v}r^{4} + \text{etc.}\}\sin\theta$$

from which we have the following:

$$X^{2} = A^{2}_{,}Q^{2}_{,} + 9A^{2}_{,,,}Q^{2}_{,,,}r^{4} + 25A^{2}_{v}Q^{2}_{v}r^{6} + 6A_{,}A_{,,,}Q_{,}Q_{,,,}r^{3} + 10A_{,}A_{v}Q_{,}Q_{v}r^{4} + 30A_{,,,}A_{v}Q_{,,,}Q_{v}r^{6} + \text{etc.}$$

$$Y^{2} = \{A^{2}_{,}Q'^{2}_{,} + A^{2}_{,,,}Q'^{2}_{,,,}r^{4} + A_{v}Q'^{2}_{v}r^{6} + 2A_{,}A_{,,,}Q'_{,}Q'_{,,,}r^{3} + 2A_{,}A_{v}Q'_{,}Q'_{v}r^{4} + 2A_{,,,}A_{v}Q'_{,,,}Q'_{v}r^{6} + \text{etc.}\}\sin^{2}\theta$$

$$XY = -\{A^{2}_{,}Q_{,}Q'_{,} + 3A^{2}_{,,,}Q_{,,,}Q'_{,,,}r^{4} + 5A^{2}_{v}Q_{v}Q'_{v}r^{6} + (2Q'_{,}Q_{,,,} + Q_{,}Q'_{,,,})A_{,}A_{,,,}r^{2} + (5Q'_{,}Q_{v} + Q_{,}Q'_{v})A_{,}A_{v}r^{4} + (5Q'_{,,,}Q_{v} + 3Q_{,,,}Q'_{v})A_{,,,}A_{v}r^{5} + \text{etc.}\}\sin\theta$$

The moment of the force tending to increase θ is

$$\Theta = -\frac{dE}{d\theta}$$

whence we may write,

$$\Theta = -\tfrac{1}{2}\alpha\{A((k_{1}-k_{2})\alpha^{2}+k_{2}) + B((k_{1}-k_{2})\alpha'^{2}+k_{2}) - C(k_{1}-k_{2})\alpha\alpha'\}$$

where

$$A = -\frac{d}{d\theta}\int_{-l}^{+l}X^{2}\,dr = \sin\theta\frac{d}{d\mu}\int_{-l}^{+l}X^{2}\,dr$$
$$B = -\frac{d}{d\theta}\int_{-l}^{+l}Y^{2}\,dr = \sin\theta\frac{d}{d\mu}\int_{-l}^{+l}Y^{2}\,dr$$
$$C = -\frac{d}{d\theta}\int_{-1}^{+l}2XY\,dr = \sin\theta\frac{d}{d\mu}\int_{-1}^{+l}2XY\,dr$$

where l is half the length of the bar and $\mu = \cos\theta$.

$$A = 4l\sin\theta\{A^{2}_{,}Q_{,}Q'_{,} + \tfrac{2}{5}A^{2}_{,,,}Q_{,,,}Q'_{,,,}l^{4} + \tfrac{2.5}{9}A^{2}_{v}Q_{v}Q'_{v}l^{6} + A_{,}A_{,,,}(Q'_{,}Q_{,,,} + Q_{,}Q'_{,,,})l^{2} + A_{,}A_{v}(Q'_{,}Q_{v} + Q_{,}Q'_{v})l^{4} + \tfrac{1.5}{7}A_{,,,}A_{v}(Q'_{,,,}Q_{v} + Q_{,,,}Q'_{v})l^{6}\}$$

$$B = 4l\sin\theta\{A^{2}_{,}(Q'_{,}Q''_{,}\sin^{2}\theta - Q'^{2}_{,}\cos\theta) + A^{2}_{,,,}(Q'_{,,,}Q''_{,,,}\sin^{2}\theta - Q'^{2}_{,,,}\cos\theta)\frac{l^{4}}{5} + A_{v}(Q'_{v}Q''_{v}\sin^{2}\theta - Q'_{v}\cos\theta)\frac{l^{6}}{9} + A_{,}A_{,,,}\Big((Q'_{,}Q''_{,,,} + Q''_{,}Q'_{,,,})\sin^{2}\theta - 2Q'_{,}Q'_{,,,}\cos\theta\Big)\frac{l^{2}}{3} + A_{,}A_{v}\Big((Q'_{,}Q''_{v} + Q''_{,}Q'_{v})\sin^{2}\theta - 2Q'_{,}Q'_{v}\cos\theta\Big)\frac{l^{4}}{5} + A_{,,,}A_{v}\Big((Q'_{,,,}Q''_{v} + Q''_{,,,}Q'_{v})\sin^{2}\theta - 2Q'_{,,,}Q'_{v}\cos\theta\Big)\frac{l^{6}}{7}\}$$

$$C = +4l\{A^{2}_{,}((Q_{,}Q''_{,} + Q'^{2}_{,})\sin^{2}\theta - Q_{,}Q'_{,}\cos\theta) + 3A^{2}_{,,,}((Q_{,,,}Q''_{,,,} + Q'^{2}_{,,,})\sin^{2}\theta - Q_{,,,}Q'_{,,,}\cos\theta)\frac{l^{4}}{5} + 5A^{2}_{v}\Big((Q_{v}Q''_{v} - Q'^{2}_{v})\sin^{2}\theta - Q_{v}Q'_{v}\cos\theta\Big)\frac{l^{6}}{9} + A_{,}A_{,,,}\Big((3Q'_{,}Q'_{,,,} + 3Q''_{,}Q_{,,,} + Q'_{,}Q'_{,,,} + Q_{,}Q''_{,,,})\sin^{2}\theta$$

$$-(3Q'_{,}Q_{,,,}+Q_{,}Q'_{,,,})\cos\theta\Big)\frac{l^2}{3}+A_{,}A_{v}\Big((5Q'_{,}Q'_{v}+5Q''_{,}Q_{v}$$
$$+Q'_{,}Q'_{v}+Q_{,}Q''_{v})\sin^2\theta-(5Q'_{,}Q_{v}+Q_{,}Q'_{v})\cos\theta\Big)\frac{l^4}{5}+A_{,,,}A_{v}\Big((5Q''_{,,,}Q_{v}$$
$$+5Q'_{,,,}Q'_{v}+3Q'_{,,,}Q'_{v}+3Q_{,,,}Q''_{v})\sin^2\theta-(5Q'_{,,,}Q_{v}$$
$$+3Q_{,,,}Q'_{v})\cos\theta\Big)\frac{l^6}{9}\Big\}$$

Where

$$\begin{aligned}
Q_{,} &= \cos\theta\\
Q_{,,,} &= \tfrac{1}{2}(5\cos^3\theta-3\cos\theta)\\
Q_{v} &= \tfrac{1}{8}(63\cos^5\theta-70\cos^3\theta+15\cos\theta)\\
Q'_{,} &= 1\\
Q'_{,,,} &= \tfrac{3}{2}(5\cos^2\theta-1)\\
Q'_{v} &= \tfrac{15}{8}(21\cos^4\theta-14\cos^2\theta+1)\\
Q''_{,} &= 0\\
Q''_{,,,} &= 15\cos\theta\\
Q''_{v} &= \tfrac{15}{2}(21\cos^3\theta-7\cos\theta)\\
\mu &= \cos\theta
\end{aligned}$$

$$A=4l\sin\theta\{(A^2_{,}+\tfrac{81}{20}A^2_{,,,}l^4+\tfrac{1875}{192}A^2_{,}l^6-3A_{,}A_{,,,}l^2+\tfrac{15}{4}A_{,}A_{v}l^4$$
$$-\tfrac{675}{56}A_{,,,}A_{v}l^6)\mu+(-27A^2_{,,,}l^4-\tfrac{4375}{24}A^2_{v}l^6+10A_{,}A_{,,,}l^2$$
$$-35A_{,}A_{v}l^4+\tfrac{4275}{28}A_{,,,}A_{v}l^6)\mu^3+(\tfrac{135}{4}A^2_{,,,}l^4+\tfrac{56625}{64}A^2_{v}l^6$$
$$+\tfrac{189}{4}A_{,}A_{v}l^4-\tfrac{3465}{8}A_{,,,}A_{v}l^6)\mu^5+(-\tfrac{6125}{4}A^2_{v}l^6+\tfrac{675}{2}A_{,,,}A_{v}l^6)\mu^7$$
$$+\tfrac{55125}{64}A^2_{,}l^6\mu^9\}$$

$$B=4l\sin\theta\{(-A^2_{,}-\tfrac{99}{20}A^2_{,,,}l^4-\tfrac{725}{64}A^2_{v}l^6+6A_{,}A_{,,,}l^2-\tfrac{45}{4}A_{,}A_{v}l^4$$
$$+\tfrac{2205}{14}A_{,,,}A_{v}l^6)\mu+(\tfrac{63}{2}A^2_{,,,}l^4-\tfrac{1575}{16}A_{v}l^6-10A_{,}A_{,,,}l^2+\tfrac{171}{4}A_{,}A_{v}l^4$$
$$-\tfrac{2475}{14}A_{,,,}A_{v}l^6)\mu^3+(-\tfrac{135}{4}A^2_{,,,}l^4-\tfrac{18225}{32}A^2_{v}l^6-\tfrac{189}{4}A_{,}A_{v}l^4$$
$$+\tfrac{945}{2}A_{,,,}A_{v}l^6)\mu^5+(\tfrac{77425}{48}A^2_{v}l^6-\tfrac{675}{2}A_{,,,}A_{v}l^6)\mu^7+\tfrac{55125}{64}A_{v}l^6\mu^9\}$$

$$C=4l\{(-A^2_{,}-\tfrac{125}{64}A^2_{v}l^6-\tfrac{1}{2}A_{,}A_{,,,}l^2+\tfrac{3}{40}A_{,}A_{v}l^4-\tfrac{5}{2}A_{,,,}A_{v}l^6)$$
$$+(-\tfrac{3}{2}A_{,}A_{,,,}l^2)\mu+(-\tfrac{297}{20}A^2_{,,,}l^4-6A_{,}A_{,,,}l^2-\tfrac{7}{2}A_{,}A_{v}l^4$$
$$+\tfrac{855}{8}A_{,,,}A_{v}l^6)\mu^2+9A_{,}A_{,,,}l^2\mu^3+(45A^2_{,,,}l^4+\tfrac{72625}{96}A^2_{v}l^6$$
$$+\tfrac{5}{2}A_{,}A_{,,,}l^2+\tfrac{511}{4}A_{,}A_{v}l^4-\tfrac{6485}{12}A_{,,,}A_{v}l^6)\mu^4-\tfrac{15}{2}A_{,}A_{,,,}l^2\mu^5$$
$$+(-\tfrac{99}{4}A^2_{,,,}l^4-\tfrac{17975}{24}A^2_{v}l^6-\tfrac{441}{5}A_{,}A_{v}l^4+\tfrac{24815}{48}A_{,,,}A_{v}l^6)\mu^6$$
$$+(\tfrac{541125}{192}A^2_{v}l^6-\tfrac{7875}{4}A_{,,,}A_{v}l^6)\mu^8\}$$

Or we can write

$$\begin{aligned}
A &= 4l\sin\theta\{L\mu+L'\mu^3+L''\mu^5+\text{etc.}\}\\
B &= 4l\sin\theta\{M\mu+M'\mu^3+\text{etc.}\}\\
C &= 2l\{N+N'\mu+N''\mu^2\text{etc.}\}
\end{aligned}$$

where the values of L, M, etc. are apparent.

To sum up we may then write as before

$$\Theta=-\tfrac{1}{2}\alpha\{A[(k_1-k_2)\alpha^2+k_2]+B[(k_1-k_2)\alpha'^2+k_2]-C(k_1-k_2)\alpha\alpha'\}$$

where A, B and C are the quantities we have found, α is the cosine of the angle made by the axis of the crystal with the axis of the bar, and α' is the cosine of the angle made by the same axis with a horizontal line at right angles to the bar.

The equation

$$\Theta = 0$$

gives equilibrium at some angle depending on α and α', and if either of these is zero the angle can be either $\theta = 0$ or $\frac{1}{2}\pi$, one of which will be stable and the other unstable according as the body is para- or dia-magnetic.

For a diamagnetic crystal like bismuth with the axis at right angles to the bar we can put

$$\mu = \cos\theta = \sin\psi \text{ and } \alpha = 0,$$

and we can write

$$\Theta = -\tfrac{1}{2}a\{4lk_2(\mathrm{L}\mu + \mathrm{L}_1\mu'^2 + \text{etc.}) + 4l[(k_1 - k_2)\alpha'^2 + k_2][\mathrm{M}\mu + \mathrm{M}'\mu^3 + \text{etc.}]\}$$

or for very small values of μ we can write in terms of ψ

$$\Theta = -2al\psi\{k_2\mathrm{L} + ((k_1 - k_2)\alpha'^2 + k_2)\mathrm{M}\}$$

If I is the moment of inertia of the bar and t is the time of a single vibration, we may write

$$\Theta = \mathrm{I}\frac{\pi^2}{t^2}\psi.$$

If we hang up the bar so that $\alpha' = 0$ we have

$$k_2(\mathrm{L} + \mathrm{M}) = -\frac{\pi^2\mathrm{I}}{2alt^2}$$

and if we hang it up so that $\alpha' = \frac{1}{2}\pi$ we have again

$$k_2\mathrm{L} + k_1\mathrm{M} = -\frac{\pi^2\mathrm{I}'}{2alt'^2}$$

whence

$$k_2 = -\frac{\pi^2\mathrm{I}}{2alt_2} - \frac{1}{\mathrm{L} + \mathrm{M}}$$

$$k_1 = -\frac{1}{\mathrm{M}}\left(\frac{\pi^2\mathrm{I}'}{2alt'^2} + k_2\mathrm{L}\right)$$

where

$$\mathrm{L} = \mathrm{A}'^2_{,} - 3\mathrm{A}_{,}\mathrm{A}_{,,,}l^2 + (\tfrac{81}{20}\mathrm{A}'^2_{,,,} + \tfrac{15}{4}\mathrm{A}_{,}\mathrm{A}_{\mathrm{V}})l^4 - \tfrac{675}{56}\mathrm{A}_{,,,}\mathrm{A}_{\mathrm{V}}l^6 + \tfrac{1875}{192}\mathrm{A}'^2_{\mathrm{V}}l^8$$

$$\mathrm{M} = -\mathrm{A}'^2_{,} + 6\mathrm{A}_{,}\mathrm{A}_{,,,}l^2 - (\tfrac{99}{20}\mathrm{A}'^2_{,,,} + \tfrac{45}{4}\mathrm{A}_{,}\mathrm{A}_{\mathrm{V}})l^4 + \tfrac{225}{14}\mathrm{A}_{,,,}\mathrm{A}_{\mathrm{V}}l^6 - \tfrac{725}{64}\mathrm{A}'^2_{\mathrm{V}}l^8$$

$$\mathrm{L} + \mathrm{M} = 3\mathrm{A}_{,}\mathrm{A}_{,,,}l^2 - (\tfrac{9}{10}\mathrm{A}'^2_{,,,} + \tfrac{15}{2}\mathrm{A}_{,}\mathrm{A}_{\mathrm{V}})l^4 + \tfrac{225}{56}\mathrm{A}_{,,,}\mathrm{A}_{\mathrm{V}}l^6 - \tfrac{75}{48}\mathrm{A}'^2_{\mathrm{V}}l^8$$

For a cleavage bar of calc spar we must use the general equation. For equilibrium we have

$$k_1\{\mathrm{A}\alpha^2 + \mathrm{B}\alpha'^2 - \mathrm{C}\alpha\alpha'\} + k_2\{\mathrm{A}(1 - \alpha^2) + \mathrm{B}(1 - \alpha'^2) + \mathrm{C}\alpha\alpha'\} = 0$$

which gives us the ratio of k_1 to k_2. For this experiment it is best to hang up the bar so that the axis is in the horizontal plane and we should then have

$$\alpha^2 = 1 - \alpha'^2$$

For obtaining another relation it is best to suspend the bar with $\alpha' = 0$ and we then have the position of stable equilibrium at the point $\theta = \frac{1}{2}\pi$, which gives

$$\Theta = -2al\psi\{L[(k_1 - k_2)\alpha^2 + k_2] + M k_2\} = \frac{\pi^2 I}{t^2}\psi,$$

whence

$$k_1 = -\frac{\pi^2 I}{2al t^2} \frac{1}{L\left[\left(1 - \frac{k_2}{k_1}\right)\alpha^2 + \frac{k_2}{k_1}\right] + M\frac{k_2}{k_1}}$$

these various equations give the complete solution of the problem of finding the various coefficients of magnetization.

PART II.—By WILLIAM W. JACQUES, Fellow in Physics of the Johns Hopkins University.

IN the foregoing part of this paper there have been deduced mathematical expressions for the constants k and k' both for bismuth and for calc-spar crystals. In these expressions it is necessary to substitute certain quantities obtained by a series of experiments, and it is the purpose of the remaining portion of the paper to describe briefly the way in which these quantities were obtained.

These experiments are naturally divided into two parts. First, the exploration of the small magnetic field between the two poles of the electromagnet, and second, the determination of the time of swing and certain other constants relating to little bars of the substances experimented upon when suspended in this field.

In order to insure the constancy of the magnetic field, a galvanometer and variable resistance were inserted in the circuit through which the magnetizing current circulated. This space between the poles of the electromagnet in which the experiments were performed was a little larger than a hen's egg.

The method of exploring this field was as follows: In the line joining the centers of the two poles was placed a little brass rod, along which a very small coil of fine wire was made to slide. To this rod were fixed two little set-screws to regulate the distance through which the coil could be moved. Starting now always from the center, the coil was moved successively through distances a, b and c, and the corresponding deflections of a delicate mirror galvanometer contained in the circuit were noted. To each of these deflections was added the deflection due to quickly pulling the coil away from the center

to a distance such that the magnetic potential was negligably small. Of course, experiments were made on both sides of the center of the field in order to eliminate any want of symmetry, and the distances through which the coil moved were all carefully measured with a dividing engine.

In order to reduce the deflections of the galvanometer to absolute measure, an earth inductor was included in the circuit with the little coil and galvanometer and the deflections produced by this were compared with those produced by moving the little coil. These deflections were taken between every two observations with the little coil.

The deflections due to moving the little coil, those due to the earth inductor and that due to pulling the coil away from the center are given in the following table:

	Distance *a*.	Distance *b*.	Distance *c*.
Coil	4·407^{cm}	9·655^{cm}	6·363^{cm}
Earth inductor	33·138^{cm}	33·137^{cm}	33·162^{cm}
Drawing coil away from center			57·416^{cm}

In order to determine the proper quantities for substitution in the expression for the magnetic potential of the field, it was necessary to measure, besides the deflections due to the little coil when moved through various distances and those due to the earth inductor.

The mean radius of the small coil	= ·3912^{cm}
Number of turns	= 83·
Width of coil	= ·1824^{cm}
Depth of coil	= ·1212^{cm}
Integral area of earth inductor	= 20716·2^{cm}
Horizontal intensity of earth's magnetism	= ·1984^{cgs}

The quotient of the mean radius of the coil by the distance moved gave tan θ.

The linear measurements were made with a dividing engine.

The horizontal intensity of the earth's magnetism was determined by measuring the time of swing of a bar magnet and its effect upon a smaller galvanometer needle. The proper substitution of these quantities in the formula given gave the expression in absolute measure for the magnetic potential at any part of the field.

The remaining part of the experiment and the part that was attended with greatest difficulty, was to prepare little bars of the substances and to determine the times of vibration of these when suspended, first with the axis vertical and then with it horizontal in the magnetic field. Besides this, the dimensions and the moment of inertia of each bar had to be determined, and, in the case of the calc-spar, the angle the bar made with the equatorial line of the poles when in its position of equilibrium, had to be measured.

Bismuth and calc-spar were the two crystals experimented upon; quite a number of other substances were tried but failed to give good results because of the iron contained in them as an impurity. The bars were each about 15^{mm} long and about 2^{mm} in cross section. The force to be measured being only about ·00000001 of that exerted in the case of iron it was necessary to carry out the experiments with the very greatest care.

In order to obtain bars free from iron, very fine crystals of chemically pure substances were selected and the bars cleaved from them. They were then polished with their various sides parallel to the cleavage planes by rubbing on clean plates of steatite with oil. In order to remove any particles of iron that might have collected upon them during these processes, they were carefully washed with boiling hydrochloric acid and with distilled water and then wrapped in clean papers, and never touched except after washing the hands with hydrochloric acid and distilled water.

In order to reduce to a minimum the causes that might interfere with the accurate determination of the times of vibration of these bars the poles of the magnet were encased by a box of glass. From the top of this a tube four feet long extended up toward the ceiling, and inside this was hung a single fiber of silk so small as to be barely visible to the naked eye. The bars were placed in little slings of coarser silk fiber and suspended by this. Outside the glass case was a microscope placed horizontally and having a focus of about six inches. This was directed toward the suspended bar, and when the latter was at rest the cross hairs of the microscope fell upon a little scratch in one end of the bar. Near by was a telegraph sounder arranged to tick seconds. The bar was set swinging through a small arc by making and breaking the current, and the interval between two successive transits of the little scratch on the bar by the cross hairs of the microscope was measured in seconds and tenths of a second by the ear. By keeping count through a large number of successive transits the time of a single swing could be determined with very great accuracy. The bar was caused to swing only through a few degrees of arc and such small correction for amplitude as was found necessary was applied. The time of swing was determined first with the axis vertical and then with it horizontal. But besides the time of swing of each bar it was necessary to measure: the length; area of section; moment of inertia in each position; and for the calc-spar bar the angle it made with the equatorial plane of the magnet when in its position of equilibrium. This was not necessary in the case of bismuth, because its position of equilibrium lay in the equatorial plane.

Bismuth.

	Time of swing.	Moment of inertia.	Half length.	Area of section.
Axis, vertical.....	7·18^{sec}	·10976^{cgs}	·7709^{cm}	·03778^{cm}
Axis, horizontal, ..	5·76^{sec}	·10943^{cgs}		

Calc-Spar.

	Time of swing.	Moment of inertia.	Half length.	Area of section.	α
Axis, vertical	46·35^{sec}	·0303^{cgs}	·8015^{cm}	·0300^{cm}	50° 30′
Axis, horizontal ...	43·39^{sec}	·0300^{cgs}			

The linear measurements were made with a dividing engine, the moments of inertia were calculated from the dimensions of the bars. The angle at which the calc-spar stood was measured by projecting the linear axis on a scale placed at a distance.

The above quantities being all determined and properly substituted, the solution of the equations gave for

Bismuth	$k_{\prime} = -$ ·000 000 012 554
	$k_{\prime\prime} = -$ ·000 000 014 324
Calc-spar.....	$k_{\prime} = -$ ·000 000 037 930
	$k_{\prime\prime} = -$ ·000 000 040 330

ART. XLIII.—*On the Vapor-Densities of Peroxide of Nitrogen, Formic Acid, Acetic Acid, and Perchloride of Phosphorus;* by J. WILLARD GIBBS.

[Continued from page 293.]

Acetic acid.—For this substance the densities have been calculated by the formula

$$\log \frac{2\cdot073\,(D - 2\cdot073)}{(4\cdot146 - D)^2} = \frac{3520}{t_c + 273} + \log p - 11\cdot349, \qquad (12)$$

the constants 3520 and 11·349 being derived from the determinations of Cahours and Bineau, which with those of Horstmann and Troost are given in Table IV. The experiments of Cahours and Horstmann were made under atmospheric pressure, those of Horstmann* by the method of Bunsen, those of Cahours presumably by the method of Dumas. The numbers in the first column of the densities observed by Cahours are taken from the twentieth volume (1845) of the Comptes Rendus, except a few cases, distinguished by parentheses, which are taken from the preceding volume (1844). The numbers in the second column are taken from his Leçons de chimie générale élémentaire, 1856. These numbers seem to be based in part

* Lieb. Ann., Suppl. VI, p. 65.

TABLE IV.—ACETIC ACID.

Experiments of CAHOURS,—HORSTMANN,—BINEAU,—TROOST.

Temperature.	Pressure.	Density calc. by eq. (12).	Density observed. Cahours. C. R.	Cahours. Legons.	Horstmann.	Excess of observed density. Cahours. C. R.	Cahours. Legons.	Horstmann.
338	(760)	2·077	2·08			·00		
336	(760)	2·077		2·082			+·005	
327	(760)	2·078	2·08	2·085		·00	+·007	
321	(760)	2·079	2·08	2·083		·00	+·004	
308	(760)	2·081		2·085			+·004	
300	(760)	2·082	2·08			·00		
295	(760)	2·084		2·083			−·001	
280	(760)	2·089	2·08			−·01		
272	(760)	2·093		2·088			−·005	
254·6	747·2	2·105			2·135			+·030
252	(760)	2·108		2·090			−·018	
250	(760)	2·111	2·08			−·03		
240	(760)	2·122		2·090			−·032	
233·5	752·8	2·132			2·195			+·063
231	(760)	2·137	(2 12)	2·101		(−·02)	−·036	
230	(760)	2·139	2·09			−·05		
219	(760)	2·165	2·17	2 132		+·01	−·033	
200	(760)	2·239	2·22	2·248		−·02	+·009	
190	(760)	2·298	2·30	2·378		·00	+·080	
181·7	749·7	2·359			2·419			+·060
180	(760)	2·376		2·438			+·062	
171	(760)	2·466	2·42			−·05		
170	(760)	2·477		2·480			+·003	
165·0	754·1	2·534			2·647			+·113
162	(760)	2·575		2·583			+·008	
160·3	751·6	2·594			2·649			+·055
160	(760)	2·601	2·48			−·12		
152	(760)	2·716	(2·72)	2·727		(·00)	+·011	
150	(760)	2·747	2·75			·00		
145	(760)	2·826	(2·75)			(−·08)		
140	(760)	2·910	2·90	2·907		−·01	−·003	
134·3	748·8	3·001			3·108			+·107
131·3	754·1	3·055			3·070			+·015
130	(760)	3·082	3·12	3·105		+·04	+·023	
128·6	752·9	3·103			3·079			−·024
125	(760)	3·168	3·20			+·03		
124	(760)	3·185		3·194			+·009	
			Bineau.		Troost.	Bineau.		Troost.
132	757	3·05	(2·86)			(−·19)		
130	59·7	2·31			2·12			−·19
130	30·6	2·21			2·10			−·11
129	633	3·03	(2·88)			(−·15)		
36·5	11·32	3·63	3·62			−·01		
35·0	11·19	3·65	3·64			−·01		
30·0	6·03	3·61	3·60			−·01		
28·0	10·03	3·75	3·75			·00		
24·0	5·75	3·71	3·70			−·01		
22·0	8·64	3·82	3·85			+·03		
22	2·70	3·59	3·56			−·03		
21·0	4·06	3·70	3·72			+·02		
20·5	10·03	3·86	3·95			+·09		
20·0	8·55	3·84	3·88			+·04		
20·0	5·56	3·77	3·77			·00		
19·0	4·00	3·73	3·75			+·02		
19	2·60	3·65	3·66			+·01		
12·0	5·23	3·88	3·92			+·04		
12	2·44	3·77	3·80			+·03		
11·5	3·76	3·84	3·88			+·04		

upon new experiments and in part upon a revision of the observations recorded in the Comptes Rendus, the calculations being carried out to another figure of decimals. They are therefore entitled to a greater weight than the numbers of the preceding column.

The agreement of the formula with the numbers given in the Leçons de chimie is very good, the greatest divergences being ·080 at 190° and ·062 at 180°. But at 190° the table in the Comptes Rendus agrees precisely with the formula, and at 171° (the next experiment) it shows a divergence in the opposite direction. The next divergences in the order of magnitude are −·033, −·036, −·032 at 219°, 231°, 240°, respectively. Here the table in the Comptes Rendus agrees substantially with that of the Leçons, but the experiments of Horstmann show a divergence to the opposite direction. In fact, the three columns of observed densities nowhere agree in the direction of their divergence from the formula.

The somewhat decided differences between the results of Horstmann and those of Cahours may be due in part to the different methods of observation, especially to the entirely different manner of applying the heat and measuring the temperature. But the higher values obtained by Horstmann cannot be accounted for by too short an exposure to the source of heat, for his experiments were made with decreasing temperatures.

The determination of Bineau are taken from the same sources as those on formic acid, the earlier determinations being distinguished as before by parentheses. One of these (at 132°) was made by the method of Dumas, the other by that of Gay-Lussac. The smallness of the observed densities appears due to the presence of water. (An acidimetric test gave 295 parts of acid in 306.) The other experiments were made with the same apparatus which was used with formic acid and show even greater regularity in their results than the experiments with that substance. Only in one case is the influence of proximity to saturation seen, viz., at 20·5° and 10·03^{mm}, the pressure of saturated vapor at this temperature being about 12·7^{mm}.* In the remaining fifteen observations of this series, notwithstanding the very low pressures employed (from 2·44 to 11·32), the greatest difference between the observations and the formula is ·04, and the average difference ·02.

The two observations by Troost† were made by the method of Dumas, but at pressures very low for this method. The results obtained differ considerably from the formula, but not so much as in the case of his experiments at low pressure with peroxide of nitrogen.

* This number is obtained from data given by Bineau by the same kind of interpolation which was used for formic acid.

† Comptes Rendus, vol. lxxxvi (1878), p. 1395.

Table V contains the experiments of Naumann* on acetic acid. These consist of ten series (distinguished by the letters

TABLE V. — ACETIC ACID.

Experiments of NAUMANN.

		TEMPERATURE.								
		78°	100°	110°	120°	130°	140°	150°	160°	185°
A	Pressure.		393·5	411	432	455	477	498·5		565
	D. calc.		3·39	3·23	3·06	2·90	2·75	2·61		2·28
	D. obs.		3·44	3·31	3·14	2·97	2·82	2·68		2·36
	Exc. of D. obs.		+·05	+·08	+·08	+·07	+·07	+·07		+·08
B	Pressure.		342·3	359·3	377·5	398·5	417·5	436·5		495
	D. calc.		3·35	3·18	3·02	2·85	2·70	2·57		2·26
	D. obs.		3·37	3·22	3·06	2·89	2·75	2·63		2·31
	Exc. of D. obs.		+·02	+·04	+·04	+·04	+·05	+·06		+·05
C	Pressure.		258							382
	D. calc.		3·26							2·22
	D. obs.		3·17							2·25
	Exc. of D. obs.		−·09							+·03
D	Pressure.		232		252	274	287·5	300		335
	D. calc.		3·23		2·87	2·72	2·58	2·46		2·21
	D. obs.		3·12		2·94	2·68	2·54	2·44		2·23
	Exc. of D. obs.		−·11		+·07	−·04	−·04	−·02		+·02
E	Pressure.	164	186	197	209	221	232	243	253	269
	D. calc.	3·53	3·15	2·97	2·81	2·65	2·52	2·41	2·32	2·18
	D. obs.	3·41	3·06	2·91	2·75	2·61	2·50	2·40	2·31	2·22
	Exc. of D. obs.	−·12	−·09	−·06	−·06	−·04	−·02	−·01	−·01	+·04
F	Pressure.	149	168			201				
	D. calc.	3·50	3·12			2·62				
	D. obs.	3·34	3·01			2·56				
	Exc. of D. obs.	−·16	−·11			−·06				
G	Pressure.	137	156	166·5	180	188	199	208·2		230
	D. calc.	3·48	3·09	2·92	2·75	2·60	2·47	2·37		2·17
	D. obs.	3·26	2·98	2·81	2·61	2·50	2·40	2·29		2·14
	Exc. of D. obs.	−·22	−·11	−·11	−·14	−·10	−·07	−·08		−·03
H	Pressure.	113	130	138·5	149	157·5	168·2	175		191·5
	D. calc.	3·42	3·03	2·85	2·69	2·55	2·43	2·33		2·15
	D. obs.	3·25	2·94	2·78	2·60	2·47	2·32	2·26		2·13
	Exc. of D. obs.	−·17	−·09	−·07	−·09	−·08	−·11	−·07		−·02
J	Pressure.	80	92	98·5	106	112·5	117·3		129·2	
	D. calc.	3·32	2·91	2·73	2·58	2·45	2·35		2·21	
	D. obs.	3·06	2·76	2·61	2·46	2·34	2·27		2·11	
	Exc. of D. obs.	−·26	−·15	−·12	−·12	−·11	−·08		−·10	
K	Pressure.	66	77·7	84	89·5	93	98	103		110·5
	D. calc.	3·26	2·85	2·68	2·53	2·40	2·31	2·24		2·12
	D. obs.	3·04	2·66	2·49	2·37	2·32	2·24	2·16		2·11
	Exc. of D. obs.	−·22	−·19	−·19	−·16	−·08	−·07	−·08		−·01

A, B, C, etc.) of observations by Hoffmann's method.† The temperatures of the observations in the different series are for

* Lieb. Ann., vol. clv, S. 325.

† This is a modification of the method of Gay-Lussac, in which the heat is supplied by a vapor bath.

the most part the same, so that for each temperature we have observations through a wide range of pressures. Within each compartment of the table are given in order the pressure of an experiment, the density calculated by equation (12), the observed density, and the excess of observed density, the temperature of the experiment being given at the head of the column. These experiments, taken by themselves, seem to show an effect of pressure upon the density about one third greater than is indicated by the formula. But the divergences (of which the greatest is ·26 and the average ·085), are not large in view of the fact that the experiments were undertaken rather with the desire of obtaining a great number of observations with moderate labor, than with the intention of attaining the greatest possible accuracy.

The quantity of acid diminishes somewhat regularly from ·2084 grams in series A to ·0185 in series K. The volume, which was 154^{cc} in the experiment at 185° in series A, diminishes in the successive series, and in the same series with diminishing temperature, to 69·6^{cc} in the experiment at 78° in series K. It is worthy of notice that the greatest deviations from the formula occur where the liability to error is most serious with respect to pressure (which was measured without a cathetometer), to volume, and to the quantity of acid.

Far more serious than the absolute amount of these divergences, is the regularity which they exhibit. But it must be remembered that the observations are by no means entirely independent, and many sources of possible error, such as the calibration of the tube and the determination of the quantity of acid, might affect the results with considerable regularity.

Only to a slight degree can the divergences from the formula be accounted for by an insufficient exposure to the temperature of the experiment. The observations, except those at 78°, were made with increasing temperatures, and the greatest divergences from the formula are not in the positive direction. Yet the positive divergences occur where we should most expect to find them, if they were due to this cause, viz., in the series in which the greatest quantities of acid were used, and in cases in which the temperature seems to have been raised at once an unusual number of degrees. (See especially the observation at 120° in series D, and in general the observations at 185°, which exhibit if not a positive at least a diminution of negative excess.) In the observations at 78°, which were the last of each series, and therefore followed a fall of temperature from 185°, we find in some cases, especially in series G, H, and J, a negative divergence much greater than in the other determinations of the same series, and which appears to be referable to this circumstance.

In Table VI are exhibited the results of experiments by Playfair and Wanklyn,* in which the vapor of the acid was diluted with hydrogen or, in a single case (the experiment at 95·5°), by air. Columns I and II of the observed densities relate each to a series of observations by the method of Gay-Lussac, column III contains four independent determinations by the method of Dumas. The numbers in the column of pressures are, as in other similar cases, the partial pressures obtained by subtracting from the total pressure (which was never very much less than that of the atmosphere) that which would be exerted by the hydrogen or air alone.

TABLE VI.—ACETIC ACID.

Experiments of PLAYFAIR and WANKLYN.

Temperature.	Pressure.	Density calc. by eq. (12).	Density observed.			Excess of observed density.		
			I.	II.	III.	I.	II.	III.
212·5	322·8	2·124		2·060			−·064	
194	326·0	2·168		2·055			−·113	
186	254·4	2·173	1·936			−·237		
182	319·4	2·213		2·108			−·105	
166·5	289·5	2·293		2·350			+·057	
163	245·8	2·290	2·017			−·273		
132	227·5	2·628	2·292			−·336		
130·5	285·7	2·729		2·426			−·303	
119	269·0	2·914		2·623			−·291	
116·5	211·3	2·876	2·371			−·505		
95·5	(123·8)	3·105			2·594			−·511
86·5	(200·4)	3·432			3·172			−·260
79·9	(83·3)	3·297			3·340			+·043
62·5	(46·2)	3·473			3·950			+·477

The first observation of the first series gives the density 1·936, which is doubtless too small, since it is much less than the theoretical limit 2·073. Since the greater part of the measurements from which this number was calculated, were also used in reducing the other observations of the series, the error probably affects the other observations, and in a somewhat increased degree. This will account only for a part of the difference between the observations and the formula. The remaining part of the differences in this series, and the somewhat smaller differences in the next, may be due to the fact that the experiments of both series were conducted with descending temperatures. Yet the experiments of the third column, which were made by Dumas' method, do not exhibit any preponderance of positive values for the excess of observed density, but rather the opposite.

On the whole, these experiments furnish no decisive indication of any influence of the hydrogen or air upon the vapor.

* Trans. Roy. Soc. Edinb., vol. xxii, p. 455.

They may be thought to corroborate slightly the tendency observed in the experiments of Naumann and Troost toward lower densities than the formula gives at very low pressures. Yet where the experiments of Naumann show the greatest deficiency in observed density (at 78° and 80^{mm}), an experiment of Playfair and Wanklyn, at almost precisely the same temperature and pressure, gives a trifling excess of observed density, and at a little lower temperature and pressure, where we should expect from the experiments of Naumann that the deficiency would be still greater, an experiment of Playfair and Wanklyn shows a great excess of density.

By combining the experiments of Cahours, Naumann and Troost, we may obtain observations of density at 130° for a very wide range of pressures. For one atmosphere, we may regard the formula as coinciding with the average of the numbers given by Cahours. For pressures between three-quarters and one-half of an atmosphere the experiments of Naumann show an excess of density; at pressures below half an atmosphere the experiments both of Naumann and of Troost show a deficiency of density as compared with the formula. For an indefinite diminution of pressure, there can be little doubt that the real density, like the value given by the formula, approaches the theoretical value 2·073. The greatest excess in the numbers obtained by experiment is ·07; the greatest deficiency is ·19, which occurs at 59·7^{mm}; the next in order of magnitude is ·11, which occurs more than once. These discrepancies are certainly such as may be accounted for by errors of observation. They do not appear to be greater than we might expect on the hypothesis of the entire correctness of the formula. On the other hand, the agreement is greater than we should expect, if we reject the theory on which the formula was obtained. It is about such as we might expect in a suitable formula of interpolation with three constants, which have been determined by the values of the density for one atmosphere, for half an atmosphere, and for infinitesimal pressures. But we must regard the actual formula, in its application to this single temperature, as having only two constants, of which one is determined so as to make the formula give the theoretical value for infinitesimal pressures, and the other so as to make it agree with the experiments of Cahours at the pressure of one atmosphere.

An entirely different method has been employed by Horstmann* to determine the vapor-density of this substance. A current of dried air is forced through the liquid acid, which is heated to promote evaporation, and the mixture of air and vapor is

* Berichte der deutschen chemischen Gesellschaft, Jahrg. iii (1870), S. 78; and Jahrg. xi (1878), S. 1287.

cooled to any desired temperature, with deposition of the excess of acid, by passing upward through a spiral tube in a suitable bath. The acid is then separated from the air, and the quantity of each determined. It is assumed that the air is exactly saturated with vapor on leaving the coil, and that it has the temperature of the bath. If we know the pressure of saturated vapor for that temperature, and assume the validity of Dalton's law, it is easy to calculate the density of the vapor. For the pressure of the air is found by subtracting the pressure of the vapor from the total pressure, (the experiments were so conducted that this was the same as the actual pressure of the atmosphere,) and the ratio of the weights of the acid and the air obtained by analysis, divided by the ratio of their pressures, will give the ratio of their densities. The pressures of saturated vapor employed by Horstmann are those given by Landolt,* and differ greatly from the determinations of Regnault, in some cases being nearly twice as great,—a difference noticed but not explained by Landolt, who however gives determinations (previously unpublished) of Wüllner, which somewhat exceed his own. (On the other hand, the observations of Bineau substantially agree with those of Regnault.)

If we compare the observations of Horstmann with the values given by equation (12), on the basis of Landolt's pressures, we find a very marked disagreement, as may be seen by the following numbers, which relate to the highest temperatures of Horstmann's experiments, where the disagreement is least.

Temperature	63·1	62·9	59·9	51·1	49·0	48·7	44·6	41·4
Pressure (Land.).....	110·0	109·2	97·0	69·0	63·4	63·0	53·1	46·6
Density calc. eq. (12)..	3·67	3·67	3·69	3·75	3·77	3·77	3·79	3·81
Density obs.....	3·19	3·11	3·12	3·16	2·89	2·98	2·75	2·62

It will be observed that while the values obtained from equation (12) increase with diminishing temperatures, the values obtained from Horstmann's experiments diminish. This diminution continues as far as the experiments go, until finally at 12° or 15° the densities are only one half as great as those obtained by Bineau, by direct experiment at the same temperatures and at somewhat less pressures, in a series of observations which bear every mark of a very exceptional precision. (Compare Tables VII and IV.) The explanation of this disagreement is doubtless to be found in the values of the pressures employed in the calculations, and it will be interesting to see how the results may be modified by the adoption of different pressures.

In determinations of the pressure of saturated vapors, too great values are so much more easily accounted for than errors in the opposite direction, especially when the pressures are small, that especial interest attaches to the lowest figures which

* Lieb. Ann., Suppl. vi (1868), p. 157.

are supported by a competent authority. The experiments of Regnault* were made with three different preparations of acetic acid, of which the second was once, and the third twice, purified by distillation over anhydrous phosphoric acid. Each distillation considerably diminished the pressure of the saturated vapor, the effect of the second distillation being about half that of the first. The numbers obtained with the third preparation are given in the following table with their logarithms, and the differences of the logarithms for one degree of temperature.

Temperature.	Pressure.	log. pressure.	diff. per 1°.
9·71	6·42	·8075	
			·0239
12·12	7·33	.8651	
			·0272
14·33	8·42	·9253	
			·0161
14·87	8·59	·9340	
			·0252
17·23	9·85	·9934	
			·0251
19·84	11·455	1·0590	
			·0237
22·37	13·15	1·1189	
			·0232
25·28	15·36	1·1864	

The uniformity of the numbers in the last column shows the remarkable precision of the determinations. At the same time it is evident that the differences in these numbers are due principally to the errors of observation, so that numbers obtained by interpolation between the logarithms of the observed pressures will be somewhat better (on account of averaging of the errors) than the original determinations.

The values obtained by such an interpolation have been used for the comparison of Horstmann's experiments with the formula (12) which is given in table VII. Unfortunately this comparison cannot be extended above 25°, which is the limit of Regnault's experiments. The first three columns of the table give the temperatures of Horstmann's experiments, the pressures corresponding to these temperatures according to the determinations of Landolt, and the density deduced from Horstmann's experiments by the use of these pressures. To these columns, which are taken from Horstmann's paper, are added the pressure derived from Regnault's observations by the logarithmic interpolation described above, the density calculated by equation (12) from these pressures and the temperatures of the first column, and the densities obtained by combining Horstmann's experiments with Regnault's pressures. This column is derived from the second, third and fourth, as follows. If w and W denote respectively the weights of vapor and of air which pass through the apparatus in the same time, P the height of the barometer, and p_L the pressure of saturated vapor as determined by Landolt, the densities obtained on the basis of Landolt's pressures, and given in the third column, are

* Mém. Acad. Sciences, vol. xxvi, p. 758. The experiments date from 1844.

evidently represented by $\frac{w(P-p_L)}{Wp_L}$. The numbers of the fifth column, which are represented in the same way by $\frac{w(P-p_R)}{Wp_R}$, where p_R denotes the pressure as determined by Regnault's experiments, have been calculated by the present writer by multiplying the numbers of the third column by $\frac{p_L(P-p_R)}{p_R(P-p_L)}$.

TABLE VII.—ACETIC ACID.

Determinations of Vapor-density by Distillation.

Temperature.	Pressure acc. to Landolt.	Density observed, Horstmann and Landolt.	Pressure acc. to Regnault.	Density calc. from Regnault's pressures by eq. (12).	Density observed, Horstmann & Regnault.	Excess of observed density. I.	Excess of observed density. II.
25·0	23·5	2·42	15·13	3·86	3·80	−·06	
23·8	22·4	2·23	14·19	3·86	3·56		−·30
22·6	21·6	2·29	13·31	3·87	3·76	−·11	
21·5	20·4	2·24	12·54	3·87	3·68	−·19	
20·4	19·2	2·05	11·81	3·88	3·37		−·51
20·2	19·0	2·28	11·68	3·88	3·75	−·13	
20·0	18·9	2·13	11·56	3·88	3·52		−·36
17·4	16·8	2·09	9·95	3·89	3·56	−·33	
15·6	15·6	1·98	8·96	3·90	3·48	−·42	
15·3	15·3	1·95	8·81	3·90	3·42		−·48
15·3	15·3	1·85	8·81	3·90	3·24		−·66
14·7	15·1	1·78	8·54	3·91	3·18	−·73	
12·7	13·7	1·96	7·60	3·91	3·56	−·35	
12·4	13·5	1·89	7·46	3·92	3·45	−·47	

As the height of the barometer in Horstmann's experiments is not given, it has been necessary to assume P=760. The inaccuracy due to this circumstance is evidently trifling. The last two columns of the table, which relate to different series of experiments by Horstmann (a distinction not observed in other parts of the table), give the excess of the densities thus obtained from Horstmann's and Regnault's experiments above the values calculated from equation (12) with the use of Regnault's determinations of pressure.

The densities obtained by experiment are without exception less than those obtained from equation (12). At the highest temperatures, where the liability to error is the least, both in respect to the measurement of the pressure of saturated vapor and in respect to the analysis of the product of distillation, the results of experiment are most uniform, and most nearly approach the numbers required by the formula. At the lowest temperatures, the greatest observed density is about one-eleventh less than that required by the formula, the difference being about the same as between the highest and lowest observed values for the same temperature.

Since each successive purification of the substance employed by Regnault diminished the pressure of its vapor, it is not improbable that the pressures might have been still farther diminished by farther purification of the substance. The pressures which we have used are therefore liable to the suspicion of being too high, and it is quite possible that more accurate values of the pressure would still farther reduce the deficiency of observed density.

Perchloride of phosphorus.—For this substance, we have at atmospheric pressure a single determination of vapor-density by Mitscherlich,* and a series of determinations by Cahours;† at lower pressures we have determinations by Wurtz‡ and by Troost and Hautefeuille.§ In the experiments of Wurtz the

TABLE VIII.—PERCHLORIDE OF PHOSPHORUS.

Experiments of MITSCHERLICH, CAHOURS, WURTZ, and TROOST and HAUTEFEUILLE.

Temperature.	Pressure.	Density calc. by eq. (18).	Density observed.		Excess of observed density.	
			Mitsch.	Cahours.	Mitsch.	Cahours.
336	(760)	3·610		3·656		+·046
327	754	3·614		3·656		+·042
300	765	3·637		3·654		+·017
289	(760)	3·656		3·69		+·034
288	763	3·659		3·67		+·011
274	755	3·701		3·84		+·139
250	751	3·862		3·991		+·129
230	746	4·159		4·302		+·142
222	753	4·344	4·85		+·506	
208	(760)	4·752		4·73		−·021
200	758	5·018		4·851		−·167
190	758	5·368		4·987		−·381
182	757	5·646		5·078		−·568
			Wurtz.	T. & H.	Wurtz.	T. & H.
178·5	227·2	5·053		5·150		+·097
175·8	253·7	5·223		5·235		+·012
167·6	221·8	5·456		5·415		−·041
154·7	221	5·926		5·619		−·307
150·1	225	6·086		5·886		−·200
148·6	244	6·169		5·964		−·205
145	391	6·45	6·55		+·10	
145	311	6·37	6·70		+·33	
145	307	6·36	6·33		−·03	
144·7	247	6·287		6·14		−·147
137	281	6·53	6·48		−·05	
137	269	6·51	6·54		+·03	
137	243	6·48	6.46		−·02	
137	234	6·47	6·42		−·05	
137	148	6·31	6·47		+·16	
129	191	6·59	6·18		−·41	
129	170	6·56	6·63		+·07	
129	165	6·55	6·31		−·24	

* Pogg. Ann., vol. xxix (1833), p. 221.

† Comptes Rendus, vol. xxi (1845), p. 625; and Annales de Chimie et de Physique, Ser. 3, vol. xx (1847), p. 369.

‡ Comptes Rendus, vol. lxxvi (1873), p. 601. § Ibid., vol. lxxxiii (1876), p. 977.

pressure was reduced by mixing the vapor with air. In Table VIII all these determinations are compared with the formula

$$\log \frac{3{\cdot}6\,(D-3{\cdot}6)}{(7{\cdot}2-D)^2} = \frac{5441}{t_c+273} + \log p - 14{\cdot}353. \qquad (13)$$

The differences between the calculated and observed values are often large, in six cases exceeding ·30; but they exhibit in general that irregularity which is characteristic of errors of observation. We should expect large errors in the observed densities, on account of the difficulty of obtaining the substance in a state of purity, and because the large value of the density renders it very sensitive to the effect of impurities which diminish the density,—also because the specific heat of the vapor is great, as shown by the numerator of the fraction in the second member of (13),* and because the density varies very rapidly with the temperature as seen by the numbers in the third column of Table VIII.

But at the two lowest temperatures of Cahours' experiments, the differences of the observed and calculated densities (·381 and ·568) are not only great, but exhibit, in connection with the adjacent numbers, a regularity which suggests a very different law from that of the formula. In fact, the densities obtained by Cahours at atmospheric pressure and those obtained by Troost and Hautefeuille at pressures a little less than one-third of an atmosphere seem to form a continuous series, notwithstanding the abrupt change of pressure. Yet it is difficult to admit that the density is independent of the pressure. So radical a difference between the behavior of this substance and that of the others which we have been considering requires unequivocal evidence. Now it is worthy of notice that the experiment at 182°, in which the greatest discrepancy is seen, is not given in the first record of the experiments, which was in the Comptes Rendus in 1845. It is given in the Annales de Chimie et de Physique in 1847, where it is called the first experiment. (The experiment at 336° is also omitted in the Comptes Rendus and that at 208° in the Annales,—otherwise the lists are the same.) If it was the first experiment in point of time, which is apparently the meaning, it was made before the publication in the Comptes Rendus, and we can only account for its omission by supposing that it was a preliminary experiment, in which its distinguished author did not feel sufficient confidence to include it at first with his other determinations, although he afterwards concluded to insert it. If we reject this observation as doubtful, the disagreement between the formula and observation, appears to be within the limits of possible

* Compare Trans. Conn. Acad., vol. iii, p. 243, and pp. 286, 287 of this volume.

error, but additional experiments will be necessary to confirm the formula.*

Experiments have also been made by M. Wurtz in which the vapor of the perchloride of phosphorus was diluted with that of the protochloride.† These experiments may be used to test equation (8), which, when the values of its constants are determined by equation (13), reduces to the form.

$$\log \frac{p_5}{p_2 p_3} = \frac{5441}{t_C + 273} - 13{\cdot}751, \qquad (14)$$

where p_5, p_2, and p_3 denote the partial pressures due respectively to the PCl_5, the Cl_2, and the PCl_3, existing as such in the gas-mixture. Since these quantities cannot be the subjects of immediate observation, a farther transformation of the equation will be convenient. Let M_3, M_2 denote the quantities of the protochloride and of chlorine of which the mixture may be formed, and P_3, P_2 the pressure which would belong to each of these if existing by itself with the same volume and temperature. These quantities will be connected by the equations

$$P_2 = \frac{kt\,M_2}{2{\cdot}22\,v}, \qquad P_3 = \frac{kt\,M_3}{4{\cdot}98\,v}, \qquad (15)$$

where k denotes the same constant as on page 286. From the evident relations

$$P_2 = p_2 + p_5, \qquad P_3 = p_3 + p_5, \qquad p = p_2 + p_3 + p_5,$$

we obtain

$$p_5 = P_2 + P_3 - p, \qquad p_2 = p - P_3, \qquad p_3 = p - P_2;$$

and by substitution of these values in equation (14),

$$\log \frac{P_2 + P_3 - p}{(p - P_3)(p - P_2)} = \frac{5441}{t_5 + 273} - 13{\cdot}751. \qquad (16)$$

In view of the relations (15), this may be regarded as an equation between the pressure, the temperature, the volume, and the quantities of protochloride of phosphorus and chlorine into which the gas-mixture is resolvable.

It is in this form that we shall apply the equation to the experiments of M. Wurtz, the results of which are exhibited in Table IX. The first column gives the number distinguishing each experiment in the original memoir; the second, the temperature; the third the observed pressure (p) of the mixture

* Additional experiments on the density of this vapor have been made by M. Cahours, concerning which he says in 1866: "Les déterminations qui je viens d'effectuer à 170 et 172 degrés (ce corps bout vers 160 à 165 degrés) m'ont donné des nombres qui, bien que notablement plus forts que ceux que j'ai obtenus antérieurement à 182 et 185 degrés, sont encore bien éloignés de celui que correspond à 4 volumes." Comptes Rendus, t. 63, p. 16. So far as the present writer has been able to ascertain, these determinations have not been published. The formula gives 6·025 for 170° and 5·973 for 172°, at atmospheric pressure. The number corresponding to four volumes is 7·20.

† Comptes Rendus, vol. lxxvi (1873), p. 601.

of PCl_5, PCl_3, and Cl_2, which is the barometric pressure corrected for the small quantity of air remaining in the flask; the fourth, the pressure π due to the *possible perchloride*, found by subtracting the pressure due to the excess of protochloride (this pressure is calculated from the theoretical density of the protochloride) from the total pressure; the fifth, the density δ of the possible perchloride calculated from its pressure π with the temperature and volume. The numbers of these five

TABLE IX.—PERCHLORIDE AND PROTOCHLORIDE OF PHOSPHORUS.

Experiments on the mixed vapors by WURTZ.

No. of exp.	t_C	p (obs.)	π	δ	P_2	P_3	p calc. by eq. (16).	Excess of obs. value of p.
XII	173·29	756·1	423	6·68	392·4	725·5	760·7	−4·6
X	165·4	748·4	413	6·80	390·1	725·5	747·9	+ ·5
VII	176·24	751·0	411	6·88	392·7	732·7	773·1	−22·1
VIII	169·35	724·1	394	7·16	391·8	721·9	750·5	−26·4
V	175·26	743·3	343	7·03	334·9	735·2	764·4	−21·1
II	164·9	758·5	338	7·38	346·4	766·9	782·9	−24·4
XI	175·75	760·0	318	7·00	309·2	751·2	776·8	−16·8
IV	175·26	756·3	271	7·06	265·7	751·0	770·9	−14·6
IX	160·47	753·5	214	7·44	221·1	760·6	766·8	−13·3
I	165·4	760·0	194	7·25	195·3	761·3	768·5	− 8·5
VI	170·34	751·2	174	8·30	200·6	777·8	787·6	−36·4
III	174·28	742·7	168	7·74	180·6	755·3	766·5	−23·8

columns are taken from the memoir cited, except that the correction of the barometric pressures has been applied by the present writer in accordance with the data furnished in that memoir. The two next columns contain the values of P_2 and P_3. These would naturally be calculated from M_2 and M_3 by equations (15). But since the values of M_2 and M_3 have not been given explicitly, those of P_2 and P_3 have been calculated from the recorded values of π and δ. Since the weight of the *possible perchloride* is $\frac{7\cdot2}{2\cdot22} M_3$, we have

$$\delta = \frac{7\cdot2\, M_3 k t}{2\cdot22\, v\, \pi} = \frac{7\cdot2}{\pi} P_3.$$

Moreover,

$$p - \pi = P_3 - P_2,$$

since both members of the equation express the pressure due to the excess of the protochloride. The values of P_2 and P_3 were obtained by these equations.

The eighth column of the table gives the values of p calculated from the preceding values of t_C, P_2, and P_3, by equation (16); and the last column, the difference of the observed and calculated values of p. The average difference is 18^{mm}, or a little more than two per cent, the observed pressure being

almost uniformly less than the calculated value. This deficiency of pressure is doubtless to be accounted for by a fact which MM. Troost and Hautefeuille have noticed in this connection. The protochloride of phosphorus deviates quite appreciably from the laws of Mariotte, Gay-Lussac, and Avogadro, the product of the volume and pressure of a given quantity of vapor at 180° and the pressure of one atmosphere being 1·548 per cent less than at the same temperature and the pressure of one-half an atmosphere.* Now we may assume as a general rule that when the product of volume and pressure of a gas is slightly less than the theoretical number (calculated by the laws of Mariotte, Gay-Lussac, and Avogadro) the difference for any same temperature is nearly proportional to the pressure.† It is therefore probable that between 160° and 180°, at pressures of about one atmosphere, the product of volume and pressure for protochloride of phosphorus is somewhat more than three per cent less than the theoretical number. The experiments of Wurtz, as exhibited in Table IX, show that the pressure, and therefore the product of volume and pressure, (we may evidently give the volume any constant value as unity,) in a mixture consisting principally of the protochloride is on the average a little more than two per cent less than is demanded by theory, the differences being greater when the proportion of the protochloride is greater. The deviation from the calculated values is therefore in the same direction and about such in quantity as we should expect.‡

M. Wurtz has remarked that the average value of δ (the density of the *possible perchloride*) is nearly identical with the theoretical density of the perchloride, and appears inclined to attribute the variations from this value to the errors of experiment. Yet it appears very distinctly in Table IX, in which the experiments are arranged according to the value of π (the pressure due to the *possible perchloride*), that δ increases as π diminishes. The experiments of MM. Troost and Hautefeuille show that the coincidence remarked by M. Wurtz is due to the fact that on the average in these experiments the deficiency of the density of the possible perchloride (compared with the

* Troost and Hautefeuille, Comptes Rendus, vol. lxxxiii (1876), p. 334.

† Andrews, "On the Gaseous State of Matter." Phil. Trans., vol. clxvi (1876), p. 447.

‡ The deviation of the protochloride of phosphorus from the laws of ideal gases shows the impossibility of any *very close* agreement between such equations as have been deduced in this paper and the results of experiment in the case of gas-mixtures in which this substance is one of the components. With respect to the question whether future experiments on the vapor of the perchloride (alone, or with an excess of chlorine or of the protochloride), will reduce the disagreement between the calculated and observed values to such magnitudes as occur in the case of the protochloride alone, it would be rash to attempt to anticipate the result of experiment.

theoretical value) is counterbalanced by the excess of density of the protochloride. When $\pi > 400$, the effect of the deficiency in the density of the possible perchloride distinctly preponderates; when $\pi < 250$, the effect of the excess of density in the protochloride distinctly preponderates. But the magnitude of the differences concerned is not such as to invalidate the general conclusion established by the experiments of M. Wurtz, that the dissociation of the perchloride may be prevented (at least approximately) by mixing it with a large quantity of the protochloride.

Table for facilitating calculation.—The numerical solution of equations (10), (11), (12) and (13) for given values of t and p may be facilitated by the use of a table. If we set

$$\Delta = \frac{D}{D_1}, \tag{17}$$

$$L = \log \frac{1000\, D_1 (D - D_1)}{(2D_1 - D)^2} = \log \frac{1000\, (\Delta - 1)}{(2 - \Delta)^2}, \tag{18}$$

we have for peroxide of nitrogen,

$$L = \frac{3118{\cdot}6}{t_C + 273} + \log p - 9{\cdot}451; \tag{19}$$

for formic acid,

$$L = \frac{3800}{t_C + 273} + \log p - 9{\cdot}641; \tag{20}$$

for acetic acid,

$$L = \frac{3520}{t_C + 273} + \log p - 8{\cdot}349; \tag{21}$$

and for perchloride of phosphorus,

$$L = \frac{5441}{t_C + 273} + \log p - 11{\cdot}353. \tag{22}$$

By these equations the values of L are easily calculated. The values of Δ may then be obtained by inspection (with interpolation when necessary) of the following table. From Δ the value of D may be obtained by multiplying by D_1, viz., by 1·589 for peroxide of nitrogen or formic acid, by 2·073 for acetic acid, and by 3·6 for perchloride of phosphorus.*

The constants of these equations are of course subject to correction by future experiments, which must also decide the more general question—in what cases, and within what limits,

* The value of Δ diminished by unity expresses the ratio of the number of the molecules of the more complex type to the whole number of molecules. Thus, if $\Delta = 1{\cdot}20$, in the case of peroxide of nitrogen there are 20 molecules of the type N_2O_4 to 80 of the type NO_2, or in the case of perchloride of phosphorus there are 20 molecules of the type PCl_5 to 40 of the type PCl_3 and 40 of the type C_2. A consideration of the varying values of Δ is therefore more instructive than that of the values of D, and it would in some respects be better to make the comparison of theory and experiment with respect to the values of Δ.

TABLE X.

For the solution of the equation: $\log \frac{1000\,(\Delta - 1)}{(2 - \Delta)^3} = \mathrm{L}$.

L	Δ	Diff.	L	Δ	Diff.	L	Δ	Diff.
·7	1·005	1	3·0	1·382	39	5·3	1·932	7
·8	1·006	2	3·1	1·421	40	5·4	1·939	6
·9	1·008	2	3·2	1·461	39	5·5	1·945	6
1·0	1·010	2	3·3	1·500	37	5·6	1·951	5
1·1	1·012	3	3·4	1·537	37	5·7	1·956	5
1·2	1·015	4	3·5	1·574	35	5·8	1·961	4
1·3	1·019	5	3·6	1·609	33	5·9	1·965	4
1·4	1·024	6	3·7	1·642	31	6·0	1·969	3
1·5	1·030	7	3·8	1·673	30	6·1	1·972	3
1·6	1·037	9	3·9	1·703	27	6·2	1·975	3
1·7	1·046	10	4·0	1·730	25	6·3	1·978	2
1·8	1·056	13	4·1	1·755	23	6·4	1·980	2
1·9	1·069	15	4·2	1·778	22	6·5	1·982	2
2·0	1·084	18	4·3	1·800	19	6·6	1·984	2
2·1	1·102	20	4·4	1·819	18	6·7	1·986	1
2·2	1·122	24	4·5	1·837	17	6·8	1·987	2
2·3	1·146	26	4·6	1·854	14	6·9	1·989	1
2·4	1·172	30	4·7	1·868	14	7·0	1·990	
2·5	1·202	32	4·8	1·882	12	7·2	1·992	
2·6	1·234	34	4·9	1·894	11	7·4	1·994	
2·7	1·268	37	5·0	1·905	10	7·6	1·995	
2·8	1·305	38	5·1	1·915	9	7·8	1·996	
2·9	1·343	39	5·2	1·924	8	8·0	1·997	
3·0	1·382		5·3	1·932		9·0	1·999	

and with what degree of approximation, the actual relations can be expressed by equations of such form. In the case of perchloride of phosphorus especially, the formula proposed requires confirmation.

ART. XLIV.—*On a secular inequality in the Moon's Motion produced by the oblateness of the Earth;* by J. N. STOCKWELL.

HAVING been engaged, during a number of years past, in a thorough and systematic examination of the physical theory of the moon's motion, it seems proper to make known to astronomers, in advance of the publication of my researches which are now essentially completed, one of the most curious and interesting results at which I have arrived relative to the motion of our satellite.

It has been known, since the time of Newton, that the attraction of a spheroidal body on a point without its surface is different from that of a sphere having the same mass. If the spheroid be one of revolution, like the earth, the attraction depends not only on the distance of the attracted point from

the earth's center, but also on its distance from the equator. If the attracted point were situated in the plane of the earth's equator the attraction of the earth upon it would be greater at a given distance than if the earth were spherical. The attraction would also be greater either north or south of the equator until we reached the paralled of about 35° 16′, at which points the attraction of the earth would be nearly independent of its spheroidal form. For all points situated beyond the parallels of 35° 16′ the attraction of the earth is less than it would be if it were spherical.

From these general considerations we may draw the following conclusions: *First.* A body would revolve round the earth, at a given distance from its center, in less time if it moved in the plane of the equator, than it would if the earth were spherical; and its motion would be uniform. *Second.* The time of revolution would be increased if the body moved in a plane inclined to the equator, and its motion would not be uniform, on account of the redundancy or deficiency of matter beneath the different parts of its course. It is evident that the motion in an orbit perpendicular to the equator would suffer greater variations from the unequal distribution of matter, than it would for any other inclination.

We shall now apply the preceding considerations to the motion of the moon around the earth, supposing for greater simplicity that her orbit is circular.

Since the inclination of the moon's orbit to the equator is always less than 35° 16′, it follows that the earth's attraction on the moon is always greater than it would be if the earth were spherical. But since the inclination varies between the limits of about 18° 19′ and 28° 35′ during a period of about nineteen years, it follows that the earth's attraction undergoes sensible variations; and hence the moon's place at any given time requires to be corrected on account of the varying inclination of its orbit to the equator. The corrections to the moon's longitude and latitude arising from this cause have been calculated, and applied to the moon's place during the whole of the present century. All these varying inequalities in the forces would accurately compensate each other during each revolution of the moon's node, provided the mean inclination of the lunar orbit to the equator always retained the same value. Now the mean inclination of the moon's orbit to the equator is the same as the inclination of the ecliptic to the same plane; and since the inclination of the ecliptic to the equator is slowly becoming less, it follows that the plane of the moon's orbit is gradually approaching the plane of the equator; and hence its mean motion must be increasing. All these various conclusions are fully confirmed by mathematical analysis, and were first suggested by it.

Having thus shown the existence of a secular inequality in the moon's motion depending on the oblateness of the earth, it only remains to determine its amount. But as a mathematical analysis of the problem is not within the scope of the present paper, I shall be content with a mere statement of the semi-general formula together with its numerical value.

If we put ε_0 for the obliquity of the ecliptic in 1850, and ε for its value at any time t, and also suppose that the ellipticity of the earth is $\frac{1}{300}$, I find the following value for the secular inequality depending on the earth's oblateness, namely:

$$\delta v = +24''\cdot827 \int (\sin^2\varepsilon_0 - \sin^2\varepsilon)dt.$$

If we develop the integral into a series and retain only the first term we shall have

$$\int (\sin^2\varepsilon_0 - \sin^2\varepsilon)dt = +0\cdot008675\, i^2,$$

in which i denotes the number of centuries counting from 1850

Hence the secular inequality becomes

$$\delta v = 0''\cdot1981\, i^2.$$

This term, though small, is of sufficient importance to be used in computing ancient eclipses.

In conclusion I would state that I have found several inequalities in the moon's motion which are not recognized by existing theories, of even greater practical interest and importance than the one to which I have called attention in this paper.

Cleveland, Oct. 2, 1879.

ART. XLV.—*Discovery of two new Asteroids;* by Professor C. H. F. PETERS. Communication to the Editors dated Litchfield Observatory of Hamilton College, Clinton, N. Y., October 6, 1879.

Two more planets of the asteroid group were found by me in the month of September, respectively on the 11th and 25th. I communicate the observations hitherto obtained.

(202) *Chryseïs.*

1879.	Ham. Coll. m. t.	App. A.	App. Decl.	No. of comp.
Sept. 11.	$12^h \pm^m$ ^{s}	$23^h\ 51^m\ 16^s\cdot$	$-\ 8°\ 53'\cdot5$	[rough estimate.]
Sept. 21.	13 18 27	23 44 15·93	− 9 58 4·4	10
Sept. 23.	12 7 56	23 42 53·47	−10 9 35·0	9
Sept. 26.	12 46 49	23 40 48·42	−10 26 55·2	10
Oct. 4.	8 56 13	23 35 39·12	−11 6 56·5	6

(203) *Pompeja.*

1879.	Ham. Coll. m. t.	App. A.	App. Decl.	No. of comp.
Sept. 25.	$14^h\ 48^m\ 21^s$	$0^h\ 57^m\ 6^s\cdot18$	$+\ 8°\ 15\ 30'\cdot4$	12
Sept. 26.	13 41 15	0 56 19·53	+ 8 12 10·9	10
Oct. 4.	10 57 30	0 49 37·80	+ 7 41 41·8	14

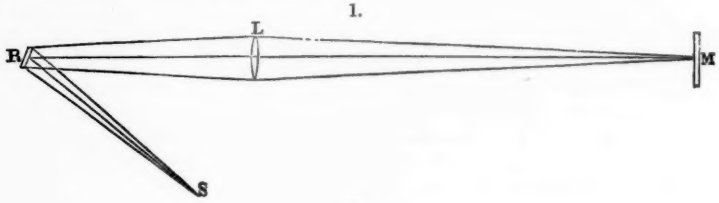
The magnitude of the first is now $11^m\cdot0$, that of the latter $10^m\cdot5$.

ART. XLVI. — *Experimental Determination of the Velocity of Light;* by ALBERT A. MICHELSON, Master, U. S. Navy.*

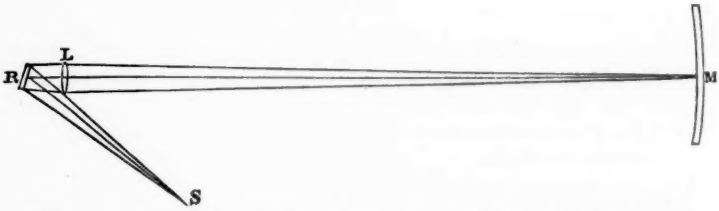
[Abstract of paper read before the American Association for the Advancement of Science.]

LET S, fig. 1, be a slit through which light passes, falling on R, a mirror free to rotate about an axis at right angles to the plane of the paper; L, a lens of great focal length, upon which the light falls, which is reflected from R. Let M be a plane mirror, whose surface is perpendicular to the line RM, passing through the centers of R, L and M, respectively. If L be so placed that an image of S is formed on the surface of M, then, this image acting as the object, its image will be formed at S, and will coincide point for point with S.

1.



2.



If, now, R be turned about the axis, so long as the light falls on the lens, an image of the slit will still be formed on the surface of the mirror, though on a different part, and as long as the returning light falls on the lens an image of this image will be formed at S, notwithstanding the change of position of the first image at M. This result, namely, the production of a stationary image of an image in motion, is absolutely essential. It was first accomplished by Foucault, and in a manner differing apparently but little from the foregoing.

In this case, L, fig. 2, served simply to form an image of S at M; and M, the returning mirror, was spherical, the center of curvature coinciding with the axis of R. The lens, L, was placed as near as possible to R. The light forming the return

* Prepared for this place by the Author.

image lasts, in this case, while the first image is sweeping over the face of the mirror, M. Hence, the greater the distance, RM, the larger must be the mirror, in order that the same quantity of light may be preserved, and its dimensions would soon become inordinate. The difficulty was partly met by Foucault, by using five concave reflectors instead of one; but even then the greatest distance he found it practicable to use was only twenty meters.

Returning to fig. 1, suppose that R is in the principal focus of the lens, L; then, if the plane mirror, M, have the same diameter as the lens, the first or moving image will remain upon M as long as the axis of the pencil of light remains on the lens, and *this will be true no matter what the distance may be.*

When the rotation of the mirror R becomes sufficiently rapid, then the flashes of light which produce the second or stationary image become blended, so that the image appears to be continuous. But now it no longer coincides with the slit, but is deflected in the direction of the rotation, and through twice the angular distance described by the mirror, during the time required for light to travel twice the distance between the mirrors. This displacement is measured by its arc, or rather, by its tangent. To make this as large as possible, the distance between the mirrors, the radius or distance from the revolving mirror to the slit, and the speed of rotation should be made as great as possible.

The second condition conflicts with the first, for the "radius" is the difference between the distances of the principal focus, and the conjugate focus (for the distant mirror). The greater the "distance," therefore, the smaller will be the "radius." There are two ways of solving the difficulty: first, by using a lens of great focal length, and, secondly, by placing the revolving mirror within the principal focus of the lens. Both means were employed. The focal length of the lens was 150 feet, and the mirror was placed fifteen feet within the principal focus. A limit is soon reached, however, for the quantity of light received diminishes very rapidly as the revolving mirror approaches the lens.

The chief objection urged in reference to the experiments made by Foucault is that the deflection was too small to be measured with the required degree of accuracy. This deflection was but a fraction of a millimeter, and when it is added that the image is always more or less indistinct on account of atmospheric disturbances, as well as imperfections of lenses and mirrors, it may well be questioned whether the results could be relied upon within less than one per cent.

In the following experiments the distance between the mirrors was nearly 2000 feet. The radius was about thirty

feet, and the speed of the mirror was about 257 revolutions per second. The deflection exceeded 133 millimeters, being about 200 times as great as that obtained by Foucault. If it were necessary it could be still further increased. This deflection was measured within three or four hundredths of a millimeter in each observation; and it is safe to say that the result, so far as it is affected by this measurement, is correct to within one ten-thousandth part.

The revolving mirror was actuated by a current of air which escaped through a turbine wheel on the same axle as the mirror. The supply of air was furnished by a blower, turned by a steam engine, the pressure being kept constant by a water-gauge attended by an assistant at the valve. To regulate and measure the speed of rotation a tuning-fork, bearing on one prong a steel mirror, was employed. This was kept in vibration by a current of electricity. The fork was so placed that the light from the revolving mirror was reflected to a piece of plane glass in front of the eye-piece, and thence reflected to the eye. When fork and mirror are both at rest, an image of the revolving mirror is perceived. When the fork vibrates, this image is drawn out into a band of light. When the mirror commences to revolve, this band breaks up into a number of moving images of the mirror; and when, finally the mirror makes as many turns as the fork makes vibrations, or any multiple, submultiple or simple ratio of this number, the images become stationary.

Hence, to make the mirror revolve at a given uniform speed, the cord attached to the valve, which leads to the observer's table, is pulled right or left, till the images of the revolving mirror come to rest.

The electric fork made about 128 vibrations per second. No dependence was placed upon this rate, however, but at each set of observations it was compared with a standard Ut_4 fork, the temperature being noted at the time.

The rate of the Ut_4 fork was found to be 256·072 at 65° F. The result obtained by Prof. Mayer and myself, at the Stevens Institute, was 256·068.

The apparatus for measuring the deflection consists of an accurate screw with divided circle. To the frame is attached an adjustable slit. On the screw travels a carriage which supports the eye-piece, which consists of an achromatic lens, having in its focus a single vertical silk fiber. The slit which is very nearly in the same focal plane as the silk fiber, is bisected by the latter, and reading of scale and circle taken. Then the screw is turned till the silk fiber bisects the deflected image of the slit, and reading taken again. The difference between the two readings gives the deflection.

[Correction, by the Author, for the table on page 393.]

Results of Observations.

Each number is the mean of ten observations.

299830	299940	299860	299870	299870
299720	299920	299860	299790	299820
299880	299940	299860	299790	299760
300050	299920	299840	299800	299790
299910	299860	299700	299780	299740
299830	299780	299700	299750	299790
299930	299830	299600	299740	299770
299960	299860	299840	299720	299790
299960	299880	299950	299730	299920
299860	299820	299930	299740	299950
299980	299810	299860	299890	299970
299960	299770	299890	299900	299970
299910	299790	299830	299870	299790
299630	299860	299850	299840	299720
299740	299860	299820	299860	299890
299790	299810	299820	299700	299920
299980	299780	299830	299820	299930
299980	299770	299820	299830	299780
299940	299740	299820	299830	299790
299940	299780	299820	299760	299850

Mean $=299838$
Cor. for temp. $= +12$ (of steel tape, etc.)

Vel. of light in air $=299850$
Cor. for vacuo $= +80$

Vel. of light in vacuo $=299930$

The direction of rotation was right-handed. To eliminate any possible error which might arise on this account, the mirror in eight of the later observations was inverted, thus making the rotation left-handed, and the deflection was measured in the opposite direction. The results agreed well with those previously obtained with the mirror erect.

To eliminate errors due to a regular variation in speed during every revolution, if any such could exist, the position of the frame was changed in several experiments. The results were the same as before.

To test the question as to whether or not the vortex of air about the mirror had any effect on the deflection, the speed was lowered to 192, 128, 96, and 64 turns per second. If the vortex had any effect, it should have decreased with the lower speed, but no such effect could be detected. This also proves that any error due to distortion of the mirror must be excessively small, otherwise it also would have been diminished with the smaller speed, thus giving different results.

Finally, to test if there were any bias in making the observations, the readings in several sets were taken by another, and written down, without divulging them. The separate readings were as consistent as when made by myself, and the results still agreed with those of the other observations.

Results of Observations.

Every number is the mean of ten separate observations.

299710	299820	299740	299790	299790
299600	299800	299740	299710	299740
299760	299820	299740	299710	299680
299880	299800	299720	299720	299710
299740	299740	299580	299700	299660
299710	299660	299580	299670	299710
299810	299710	299480	299660	299690
299840	299740	299720	299640	299710
299840	299760	299830	299650	299770
299740	299700	299810	299660	299800
299860	299690	299740	299810	299820
299840	299650	299770	299820	299820
299790	299670	299710	299790	299710
299510	299740	299730	299760	299640
299620	299740	299740	299780	299810
299670	299690	299740	299620	299840
299860	299660	299750	299740	299780
299860	299650	299710	299750	299580
299820	299620	299740	299750	299560
299820	299660	299740	299680	299610

Mean result	299728
Cor. for temp.	+12 (of steel tape, scale and screw).
Vel. of light in air	299740
Cor. for vacuo	+80

Vel. of light in vacuo 299820 kilometers per second.

ART. XLVII.—*The Kane Geyser Well;* by CHARLES A. ASHBURNER, Assistant Second Geological Survey of Penn.*

THE Kane Geyser or Spouting Water-well, which during the past year has attracted such general attention from the "sight-seeing" public, is no novelty to the oil man. The cause of the action has been so erroneously represented, that a correct explanation seems to be demanded.

This well is situated in the valley of Wilson's Run, near the line of the Philadelphia and Erie Railroad, four miles southeast from Kane. It was drilled by Messrs. Gruhout and Taylor in the spring of 1878 to a total depth of 2,000 feet. No petroleum was found in paying quantities and the casing was drawn and the hole abandoned, since which time it has been throwing periodically—every ten to fifteen minutes—a column of water and gas to heights varying from 100 to 150 feet.

During the operation of drilling, fresh "water veins" were encountered down to a depth of 364 feet, which was the limit of the casing. At a depth of 1415 feet a very heavy "gas vein" was struck. This gas was permitted a free escape during the time the drilling was continued to 2,000 feet.

When the well was abandoned, from failure to find oil, and the casing drawn, the fresh water flowed into the well and the conflict between the water and gas commenced, rendering the well an object of great interest. The water flows into the well

* The above notice of this remarkable water-and-gas geyser is from Stowell's Petroleum Reporter (Pittsburgh, Pa.) for Sept. 15th. The view of the Geyser is copied from a photograph sent to the editors by Mr. Ashburner. A fuller description of a similar and adjoining well by Mr. Ashburner appeared in 1877 in the Transactions of the American Philosophical Society, and is noticed in this Journal in volume xvi, at page 140, 1878.

on top of the gas, until the pressure of the confined gas becomes greater than the weight of the superincumbent water, when an expulsion takes place and a column of water and gas is thrown to a great height. This occurs at present at regular intervals of thirteen minutes and the spouting continues for one and a half minutes. On July 31, Mr. Sheafer (aid, McKean County) measured two columns, which went to heights respectively of 120 and 128 feet. On the evening of August 2d, I measured four columns in succession and the water was thrown to the following heights: 108, 132, 120 and 138 feet. The columns are composed of mingled water and gas, the latter being readily ignited. After night-fall the spectacle is grand. The antagonistic elements of fire and water are so promiscuously blended, that each seems to be fighting for the mastery. At one moment the flame is almost entirely extinguished, only to burst forth at the next instant with increased energy and greater brilliancy. During sunshine the sprays form an artificial rainbow, and in winter the columns became incased in huge transparent ice chimneys.

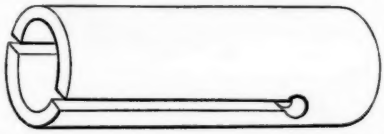
A number of wells in the oil regions have thrown water geysers similar to the Kane well, but none have ever attracted such attention.

As early as 1833 a salt well, drilled in the valley of the Ohio, threw columns of water and gas, at intervals of ten to twelve hours, to heights varying from fifty to one hundred feet. This well is possibly the first of the "water and gas geyser wells."

ART. XLVIII.—*On a Resonant Tuning Fork;* by THOMAS A. EDISON, Ph.D., Menlo Park, N. J.

[Read at the Saratoga meeting of the American Association.]

FOR the purpose of rendering audible the sounds produced by tuning forks, they are generally mounted upon resonant boxes containing a column of air whose vibrating period is the same as that of the fork. I have devised a modification of this



plan, by which the box is dispensed with, the resonant chamber, as is shown in the cut, being formed by the prongs themselves. To make the fork, a thick tube of bell-metal, one end of which is closed, has a slit sawed longitudinally through its

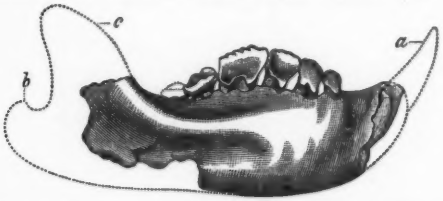
center, the slit being nearly to the closed end. This slit divides the tube equally and gives two vibrating prongs, analogous to those of a fork. To bring the prongs into unison with the column of air between them, the tube is put in a lathe and turned thinner until the desired point is reached and the two are in unison. Thereupon the sound of the fork is powerfully reinforced.

ART. XLIX.—*Notice of New Jurassic Mammals;* by Prof. O. C. MARSH.

ADDITIONAL remains of mammals from the Jurassic of the Rocky Mountains indicate that this class constituted an important element in the Mesozoic fauna of this country. The forms already described,* as well as those noticed below, show moreover, such a resemblance to known types from the Purbeck of England, that some connection between the two faunæ is clearly implied, and future discoveries will be awaited with interest.

Ctenacodon serratus, gen. et sp. nov.

One of the most interesting specimens yet brought to light is a diminutive right lower jaw, with most of the teeth in excellent preservation. This specimen differs widely from the remains hitherto found in this country, but agrees in its main features with the genus *Plagiaulax* of Falconer.† From the type species of that genus (*P. Beckelsii*), it differs in having four lower premolars instead of three; while from all the described species, it may be distinguished by the absence of the characteristic oblique grooves on the sides of the premolar crowns. This specimen is represented in the figure given below.



Right lower jaw of *Ctenacodon serratus*, Marsh; about four times natural size.
a. incisor; *b.* condyle; *c.* coronoid process.

This lower jaw is short and massive. Its outer surface is marked by a strong ridge, which begins below the first premolar, and is continued to the base of the coronoid process.

* This Journal, vol. xv, p. 459, 1878; vol. xviii, pp. 60 and 215, 1879.
† Journal Geological Society of London, vol. xiii, p. 261. 1857.

The symphysis is short, and the two rami were not firmly coössified. The lower dental series is as follows:

Incisors 1–1; premolars 4–4; molars 2–2.

The incisor was large, and had a compressed base. The premolars are wedge-shaped, and all have sharp trenchant crowns. The summit of each is very thin, and the last is distinctly serrated. The first lower molar had a low crown, very similar to that of *Plagiaulax*.

The following are the principal dimensions of this specimen:

Length of portion preserved	11· mm
Space occupied by lower teeth	8·5
Space occupied by four premolars	4·5
Depth of jaw below first premolar	2·5
Depth of jaw below last premolar	3·5
Height of crown of last premolar	1·5

A second specimen, also a right lower jaw, agrees essentially with the one here described. Both are from the same locality, in the Atlantosaurus beds of Wyoming. These fossils, with those of the genus *Plagiaulax*, belong to a well marked family, which may appropriately be termed *Plagiaulacidæ*.

Dryolestes arcuatus, sp. nov.

A third species of *Dryolestes* is at present represented by five specimens, two upper, and three lower jaws. This species may be distinguished from those already described by the upper and lower molar teeth, which are small, crowded together, and placed on a curve, the former with the convexity outward. The specimen which may be regarded as the type of this species is an upper jaw, with six molar teeth in place. Between these and the canine, there were at least four premolars. The teeth of the lower jaw were small, and numerous, and in one specimen appear to have been arranged on a curve opposite to that of the upper molars.

The principal measurements of the type specimen are as follows:

Space occupied by teeth in maxillary	15· mm
Space occupied by six posterior molars	7·
Height of maxillary above second premolar	5·
Space occupied by first three upper molars	3·5

The known remains of this species indicate an animal about as large as a weasel. The species now described represent a distinct family, which may be called *Dryolestidæ*.

Tinodon robustus, sp. nov.

A species of this genus, about twice as large as the one previously described (*T. bellus*), is indicated by a lower jaw with

several teeth in good preservation. The lower molars have a strong basal ridge on the inner surface of their crowns. The ramus of the lower jaw is compressed. The mylo-hyoid groove is well marked, and is continued forward much further than in the smaller species.

The main dimensions of this specimen are as follows:

Space occupied by four lower molars	9· mm
Depth of jaw below first lower molar	4·
Depth of jaw below last lower molar	5·
Height of penultimate molar above inner side of jaw	2·

This specimen pertained to an animal about the size of the preceding species.

Tinodon lepidus, sp. nov.

Another species of *Tinodon*, the smallest yet found, is represented by a left lower jaw, in fair preservation. This specimen differs from the type of *T. bellus*, which it most resembles in size, in having smaller teeth, the inner margin of the jaw somewhat inflected, and the angle extending downward below the condyle, instead of being emarginate at this point. The condyle, moreover, is on a level with the base of the teeth, and not above their crowns, as in the type species.

The present specimen measures as follows:

Distance from first molar to end of condyle	15· mm
Space occupied by four molar teeth	6·
Depth of jaw below first lower molar	2·5
Depth of jaw below condyle	2·

All the specimens here described are from the same locality, in the Upper Jurassic of Wyoming, and are now preserved in the Yale Museum.

Yale College, New Haven, October 22d, 1879.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a new method of preparing Hyponitrous acid.*—Since the method of preparing sodium hyponitrite by reducing sodium nitrite with sodium amalgam is long and tedious and the yield small, Zorn has devised an electrolytic method for producing it, which works well. At first he used platinum electrodes in a concentrated solution of sodium nitrite; but with no result. He then made the negative electrode of mercury, using four Bunsen cells. A pretty active evolution of gas begins in a short time, the gas, however, containing no ammonia. If the current be broken after a short time, the liquid neutralized with acetic acid, and treated

with silver nitrate, an abundant precipitate of silver hyponitrite, $AgNO$, is thrown down. If the electrolysis be continued too long, i. e., after the evolution of ammonia begins, the silver hyponitrite falls as before on adding silver nitrate to the neutralized liquid, but is immediately decomposed with evolution of gas and deposition of metallic silver. This reaction shows, therefore, the production of hydroxylamine in this electrolysis. The yield of hyponitrite is good and the author recommends this process as much preferable to that by sodium.—*Ber. Berl. Chem. Ges.*, xii, 1509, Sept., 1879. G. F. B.

2. *On the Direct Union of Calcium oxide and Carbon dioxide.*—It is well known that at a high temperature, calcium oxide unites directly with carbon dioxide, while they have no action at ordinary temperatures. BIRNBAUM and MAHN have sought to determine more exactly the temperature at which this action commences. Pure lime was prepared by igniting marble in a platinum crucible, slaking it with water repeatedly and igniting until the weight was constant. Pure dry carbon dioxide was passed over weighed portions of this lime, contained first in a boat in a porcelain tube, and afterward in a bulb of Bohemian glass, the heat being that of a paraffin bath heated from 160° to 320° C. The weight remained unchanged. Experiments made with baths of lead and tin alloys fusing at from 230° to 290°, or of pure lead fusing at 236·2°, gave the same result. The first absorption was observed when the bulb was placed in melted zinc, 415·3°. After five to eight hours, 100 parts of lime absorbed 4·1 per cent CO_2, after thirteen hours 15·2 per cent, after forty hours 31·6 per cent, and after fifty hours 45·7 per cent. Since 100 parts of lime requires 78·57 parts CO_2, but a little more than half the quantity required to form $CaCO_3$ was taken up in this time. On heating for sixty hours, only 21·1 per cent was absorbed. Hence dissociation must also take place at this temperature. To test the question, precipitated calcium carbonate was treated in a slow current of dry air in the zinc bath. After ten hours 0·78 grams had lost 0·011 grams; but farther heating did not increase this quantity. The temperature of union and of dissociation of calcium carbonate is therefore about 400°.—*Ber. Berl. Chem. Ges.*, xii, 1547, Sept., 1879. G. F. B.

3. *On the new Element, Scandium.*—CLÈVE has studied the new earth scandia, discovered by him, a few weeks after Nilson's announcement of it, in gadolinite and yttrotitanite, the former containing 0·002 to 0·003 and the latter 0·005 per cent of scandium. Scandia has the formula Sc_2O_3, ammonio- and potassio-scandium sulphates, and also the oxalates and selenites, establishing it. From eight to ten grams of scandia, by repeated decompositions of the nitrate, one gram of a white earth was obtained. This was converted into sulphate and calcined; 1·451 grams gave 0·5293 of scandia, which gives for the atomic weight of scandium 44·01. If scandia be taken as ScO, the above result gives as its molecular weight 45·94; differing essentially from 105·83 the minimum

value given by Nilson. Careful examination by Thalén with the spectroscope, proved Clève's scandia to be pure; hence he infers that in the 0·3298 gram of scandia on which Nilson worked there must have been only 0·043 of scandia and seven or eight times as much ytterbia. Clève concludes on 45 as the atomic weight of scandium. Scandia Sc_2O_3 is a perfectly white light powder, infusible and resembling magnesia. Acids, even the strongest, attack it with difficulty; still, it is more soluble than alumina. Its density is about 3·8. The hydrate is white and bulky like that of alumina. It does not attract CO_2 from the air, is insoluble in excess of ammonium or potassium hydrates, and does not decompose salts of ammonium. Its salts are colorless, with an acid and astringent taste, quite different from the sweet taste of the other yttria-earth salts. The sulphate does not give distinct crystals; but the nitrate, oxalate, acetate, and formate are crystallizable. The chloride gives no spectrum when heated in a gas flame. Its solution is precipitated by ammonium and potassium hydrates, the precipitate being insoluble in excess. Tartaric acid prevents the precipitation by ammonia in the cold. Sodium carbonate gives a precipitate soluble in excess. H_2S gives no precipitate, $(NH_4)HS$ throws down the hydrate, sodium phosphate gives a gelatinous precipitate. Oxalic acid gives a curdy precipitate which becomes rapidly crystalline. Sodium hyposulphite and sodium acetate precipitate readily boiling solutions, though incompletely. What renders the discovery of scandium particularly interesting is the fact that its existence and properties were predicted by Mendelejeff, as a consequence of his law of periodicity, and called *ekabor*. The remarkably close correspondence of the properties of ekabor with those of scandium is shown by printing them in parallel columns in Clève's memoir.—*C. R.*, lxxxix, 419, Aug., 1879.

G. F. B.

4. *On two new Elements, Thulium and Holmium.*—Since the ytterbium of Marignac and the scandium of Nilson, both of which were discovered in erbia, give colorless salts, CLÈVE has sought to distinguish the substance in this earth which gives the red color and the beautiful absorption spectrum to its salts, in order to ascertain if it was erbium itself. Using the residues from which Nilson had separated the ytterbia and the scandia, he found it impossible to obtain a red oxide with a constant molecular weight, even after several hundred decompositions. Suspecting the presence of an unknown oxide, he applied to Thalèn to examine the spectrum of what he regarded as the purest erbia, and to compare it with that of yttria and of ytterbia. Certain absorption bands in the last fractions suggested that the color of erbia is due to the presence of three oxides giving absorption spectra. The reddest of the fractions (RO mol. wt., 126–127) were united and submitted to a long series of decompositions, one fraction being treated for ytterbia, another for yttria, and a third, intermediate, containing the concentrated erbia. At the same time, he attempted to concentrate the coloring matter in residues A, rich

in ytterbia, and B in yttria. After pushing the treatment as far as possible with the amount of material in hand, he submitted the five fractions to Thalèn, who found bands common to all the fractions and hence due probably to erbia. These had the following wave-lengths: 6660–6680 (weak), 6515–6545 (strong), 6475–6515 (quite strong), 5400–5415 (quite strong), 5225–5235 (very strong), 5185–5225 (strong), 4865–4877 (strong), 4475–4515 (quite strong). The following bands varied markedly from one fraction to another:

		Fraction A.		*Erbium?*	*Fraction B.*	
	Wave-length.	Extr. from ytterbia residues.	Extr. from erbia 126-7.	Mean fractions 126-7.	Extr. from erbia 126-7.	Extr. from residues rich in yttrium.
x	6480	strong	quite strong	fails	fails	fails
y	6400–6425	fails or trace	trace	weak	weak	pretty strong
z	5360	fails	fails or trace	trace	feeble	quite strong

Hence *x* belongs to fractions situated near ytterbia and does not exist in fractions from yttrium. But, on the other hand, *y* and *z* fail in the ytterbium residues but grow sharper as yttrium is approached. The ytterbia fractions gave a rose color, with a tinge of violet; the yttria fractions had an orange tint. For the element between ytterbia and erbia, characterized by band *x* in the red of the spectrum, Clève proposes the name *Thulium*, from Thule, the ancient name of Scandinavia. The atomic weight, Tm, should be about 113 if its oxide is RO. Erbium proper, which has the common bands mentioned, has the atomic weight 110–111. Its oxide is of a clear rose color. The third metal present, characterized by the *y* and *z* bands, and which is between erbia and terbia, should have an atomic weight below 108. Its oxide appears to be yellow. For it, the name *Holmium* is proposed, derived from the Latin name of Stockholm, the environs of which are rich in yttria minerals.— *C. R.*, lxxxix, 478, Sept., 1879.

G. F. B.

5. *Notes on the two new Elements announced by Clève.*—SORET has called attention to the fact that he pointed out in the spring of 1878, the two bands which characterize holmium, as not belonging to erbia, but to a new earth which he called provisionally X and which is perhaps identical with philippium since discovered by Delafontaine. Beside these two bands, Soret recognized three other absorption bands; one less refrangible than A, a second overlapping the band of erbia in the indigo, and a third, faint, in the violet a little beyond *h*. In the ultra violet-spectrum six absorption-maxima exist from H to R. In samarskite, the earth X is, relatively to erbia much more abundant than in gadolinite. As to the red ray which characterizes thulium, Soret had already observed that also in some ytterbia products which had been sent to him for examination by Marignac. LECOQ DE BOISBAUDRAN confirms Soret's statement in regard to the red thulium ray, hav-

ing observed it in a sample of impure ytterbia which he had received from the latter some months ago. He inclined to the belief that all the bands were due to erbia, modified by the conditions. But special experiments led him to coincide in Soret's views and to conclude in the possibility that erbia was a mixture of three oxides.—*C. R.*, lxxxix, Sept., 1879. G. F. B.

6. *An Introduction to the Practice of Commercial Organic Analysis;* being a Treatise on the properties, proximate analytical examination, and modes of assaying the various organic chemicals and preparations employed in the Arts, Manufactures, Medicine, etc. With concise methods for the Detection and Determination of their Impurities, Adulterations and Products of decomposition; by ALFRED H. ALLEN, F.C.S., Lecturer on Chemistry at the Sheffield School of Medicine, etc. Volume I. Philadelphia, 1879. (Lindsay & Blackiston.)—In preparing this book, Mr. Allen has done a good service for the public analyst. The great activity in organic research in recent years has resulted in the production of a large number of compounds whose valuable properties have led to their commercial utilization. Except, however, in the original memoirs where they were described, the properties and reactions of many of these compounds have remained comparatively unknown, and hence their adulteration has been an easy matter. In gathering together the physical and chemical properties of these substances into a convenient volume, and especially in doing this with the care and scientific accuracy which Mr. Allen has evidently exercised, a valuable aid has been rendered in protecting the public from imposition. The volume before us is the first of two which the author has projected. After a brief introduction, in which are given the methods of the preliminary examination of organic bodies, the study of their physical properties, their solubility in various menstrua, their ultimate or elementary analysis, and the production of definite compounds from, and the products of decomposition of, organic bodies, the author takes up several classes of these organic bodies in the following order: Cyanogen and its derivatives, alcohols, neutral alcoholic derivatives, acid alcoholic derivatives and vegetable acids, phenols, and the acid derivatives of phenols. The individual members of each class which are of commercial importance are, in general, quite fully considered, their origin, mode of preparation, physical and chemical properties, reactions, and adulterations, being discussed in order. This portion of the work appears to be entirely reliable, and leads us to hope that the second volume may soon be forthcoming. In reproducing it here, the American publishers have strengthened the cause of sanitary chemistry in this country.

G. F. B.

7. *Laboratory Teaching:* or Progressive Exercises in Practical Chemistry; by CHARLES LONDON BLOXAM, Professor of Chemistry in King's College, London, etc. Fourth Edition, with eighty-nine illustrations. Philadelphia, 1879. (Lindsay & Blakiston.)—Chemical text-books may be divided into two classes,

those which teach Chemistry as a science and aim to make chemists, and those which teach it as an art and aim to make analysts. Professor Bloxam's book, to judge from the somewhat extraordinary preface to the fourth edition, belongs evidently to the latter class. He says: "The most important alteration in the present edition is the introduction of the formulæ representing the various chemical compounds described in the notes to the tables. The formulæ are those now generally employed by chemical writers and teachers in this country. The verbal description of the composition, in the Tables of Common Compounds of the several metals, has not been altered so as to bring it into perfect harmony with the formulæ, since the description there given generally informs the learner what substances can be obtained by the decomposition of the Common Compounds which is not so easily to be ascertained by an inspection of the formulæ. For example, the composition of saltpeter is described at page 81 as Potash (Potassium and Oxygen) and Nitric Acid, while the formula KNO_3 does not indicate the presence of potash (K_2O) or of nitric acid (HNO_3); but both these substances are obtainable from saltpeter by very simple chemical operations, and saltpeter may be produced by causing them to act upon each other. It is true that similar reasoning would justify the statement that common salt contained soda and hydrochloric acid instead of sodium and chlorine, but the author feels that an endeavor to be absolutely consistent would injure the practical usefulness of so small a book." Hence we are not surprised to find that Na_2SO_4 is called sulphate of soda and that it is said to be composed of soda and sulphuric acid; or to be told that sulphate of ammonia $(NH_4)_2SO_4$, is composed of ammonia, water, and sulphuric acid. In the first edition, it is claimed as a merit that the book "does not enter into any theoretical speculations." In the light of the preface to the fourth edition and of the instances just quoted, we have to differ from that opinion, reminding the author that unexploded theories are less dangerous to teach, than exploded ones. Viewed from the author's stand-point, however, the book has some good points. The methods of manipulation are well described and illustrated, the leading reactions of the more commonly occurring substances are clearly given, and the processes for the qualitative determination of unknown mixtures are plainly tabulated. The mechanical execution of the book is excellent. G. F. B.

8. *Solar Physics.* — On the occasion of the partial eclipse observed at Marseilles on the 19th of July, 1879, M. Janssen applied the photographic method of observing contacts. The observation of partial eclipses have long been considered inaccurate for the determination of position; the difficulties of taking precise micrometric measurements upon the sun and the determination of the instant of contact are well known. M. Janssen proposes to take, by means of a *revolver*, a number of solar images of $0^m{\cdot}06$ to $0^m{\cdot}10$ in diameter, at intervals of one second. By optical methods the contacts cannot be observed with precision, on

account of the small deformation of the solar disc, when the moon encroaches upon it. With the *revolver* one can obtain a series of negatives which include the critical moment of contact. These negatives can be examined at leisure. These photographs also can be used to determine the relative position of the two heavenly bodies at the different intervals of time, and by this means check the above method of observing contacts. The method is also of use in studying the character of the sun's surface. If the moon's disc is absolutely free from a gaseous envelope, the solar granulation preserves its forms and its character up to the edge of the occulting moon. If, however, a gaseous envelope of considerable size interposes itself, it will act under the most favorable conditions for producing these deformations by refraction. The existence and the value of these deformations of the granulations at the edge of the occulting moon will therefore become a very sure test of the presence and density of this atmosphere. This method also allows of the determination of the height of the lunar mountains situated on the edge of the moon's limb, in a position where the methods of measurement hitherto used have been the most difficult and the most inexact. The photographs of the edge of the sun upon which the moon's limb encroaches gives the contour of all the inequalities of the surface of the moon which are projected upon the sun. By micrometric measurements and comparison with the sun's disc, one can readily obtain the relative size of these inequalities of surface. These measurements together with those of the angles they subtend, as seen from the earth, afford the means of obtaining their true size. This method of observation was employed on the occasion of the late eclipse at Marseilles. Some solar photographs $0^{m}{\cdot}30$ in diameter were taken. These photographs show the granulations; but do not give any evidence of a change on the moon's limb. They however show very clearly the inequalities of the lunar contour, and allow of micrometric measurements of the heights of these inequalities.—*Comptes Rendus*, No. 6, 1879, p. 340. J. T.

9. *Density of the light Ether.*—Herr P. Glan criticizes the conclusions of Sir William Thomson that the mass M of a cubic foot of ether is greater than $\frac{83g}{V^2n^2}$ pounds, where g is the gravitation constant, V the velocity of light, and n the ratio of the greatest velocity of a rotating ether particle to the velocity of light. The value of n taken by Thomson is $\frac{1}{10}$ and the resulting value of M is greater than $\frac{1}{1560\,1017}$ pound. According to Thomson it lies in the nature of wave-movement that the ratio of the greatest velocity of a swinging particle to the velocity of light must be small, and if the ratio $\frac{1}{10}$ is taken the resulting value of M must be below the true value. Herr Glan, from theoretical conclusions upon the limit of actual disruption of the ether, doubts the conclusions of Thomson. The passage of the heavenly bodies through the ether of space must tend to separate the ether particles, and since the ether offers no sensible opposition to the pas-

sage of these bodies, it is concluded that very little energy is needed to effect any separation of ether particles which may take place, and the greatest possible dilatation of this ether must be much smaller than is the case with glass or water. In comparing authorities, Herr Glan finds that taking the greatest possible dilatation of glass before disruption at $\frac{1}{1443}$ the value of $n=\frac{1}{21}$ which is twice the value taken by Thomson. For the greatest possible dilatation of water under the same conditions, the value of $\frac{1}{37}\cdot\frac{1}{106}$ is taken. This gives the value $n=\frac{1}{4306}$ if the dilatation of the ether before disruption is as great as in the case of water. This value of n shows that the ether in a definite space possesses more mass than the hundred billionth part of this space, if it were filled with hydrogen at its normal density. The lower limit of the density of ether, according to this calculation, would therefore be 7416 times greater than that given by Thomson.—*Annalen der Physik und Chemie*, No. 8, 1879, p. 640. J. T.

10. *Mechanical Equivalent of Heat.*—H. Carnot has presented to the French Academy a series of his brother Sadi's manuscripts written between 1824 and 1832. From these papers it appears that Sadi Carnot had discovered the mechanical equivalence of heat and work. The following is an extract from these papers: "Heat is then the result of a movement. It can be produced by the consumption of motive power, and it can produce this power. When there is destruction of motive power, there is at the same time a production of heat exactly equivalent to the motive power destroyed. Reciprocally when there is destruction of heat there is production of motive power. According to some ideas which I have formed upon the theory of heat, the production of a unit of motive power necessitates the destruction of 2·70 units of heat." The unit of work taken is that which will lift one cubic centimeter of water one meter high. This unit is 1000 kilogrammeters. The mechanical equivalent of heat, according to this, would be $\frac{1000}{2\cdot71}$ =370 kilogrammeters. The first determination of Mayer in 1842 gave 365 kilogrammeters. Joule's result is 425. The publication of this result of Carnot was prevented by his death, which occurred at the early age of 36.—*Beiblatter, Annalen der Physik und Chemie*, No. 8, 1879, p. 584. J. T.

11. *Units and Physical Constants;* by Professor J. D. Everett. 175 pp., small 8vo. London, 1879. (Macmillan & Co.).—The author of this work was the Secretary of the Committee of the British Association appointed with reference to "the selection and nomenclature of dynamical and electrical units." In 1875 he prepared a volume of illustrations of the C. G. S. system (or centimeter-gram-second system) of units, adopted by this Committee, and of this volume the present work is substantially a second edition. It appears, however, in a much enlarged form, and under a different name. The importance to the physicist of having the many physical constants referred to a uniform series of fundamental units can hardly be over-estimated, and hence the great value of Professor Everett's book, in which this end is accomplished.

12. *Elementary Lessons on Sound;* by Dr. W. H. STONE. 191 pp. 12mo. London, 1879. (Macmillan & Co.).—The fundamental principles of Acoustics are fully and clearly stated and illustrated with numerous figures and practical examples. From them the author passes to the development of the theory of music, and explains it, so far as space permits, in a very clear and satisfactory manner. He makes use of the results of the more recent investigations in this field, and thus puts within the reach of the student much that would otherwise be inaccessible to him.

II. GEOLOGY AND MINERALOGY.

1. *On some points connected with the igneous eruptions along the Cascade Mountains of Oregon;* by Rev. THOMAS CONDON. (From a letter to J. D. Dana, dated Eugene City, Oregon, July 1, 1879.)—[The letter was written in reply to an inquiry respecting the continuity of the lavas of Mt. Hood and the Cascade Region with those of Mt. Adams and Mt. St. Helens, and relating to other points bearing on the extent of the eruptions southward along the Cascade range.—J. D. D.]

The Cascade range from Klamath River, south of the Columbia, to Mt. Rainier, on the north, has somewhat of the outline of a prostrate tree, far gone to decay. The main trunk is well represented by the main range; and at almost regular intervals along the whole line, we find, lying by its side, the remnants of its former limbs; not entire limbs now, but the knots that survive to represent them. Beginning at the north we find in the Simcoe Mountains, directly east of Mt. Adams, an evident outflow of eruptive material from that center; tilted and broken, yet in line. Twenty-five or thirty miles south of Simcoe Mountain, we find another such in the Klikitat Mountain; at the foot of which flows the Columbia River, and by whose help and guidance, the Columbia was enabled to penetrate and break through the range itself at the Cascades. This Klikitat Mountain is 2,000 feet high, and its beds are warped and tilted, showing that, like the Simcoe Mountain, it was subjected to the full measure of the violence that here closed the Miocene Tertiary. Thirty miles south of this is another elevation, known here as the Des Chutes Hill. This, too, is basalt, flexed and tilted, and broken, yet continuous; an evident outflow from the neighborhood of Mt. Hood.

Others may be traced farther south. Now all these hills have the following common characteristics: first, they are of eruptive origin; secondly, the dip is regularly away from the main range, from whose summit or sides they once flowed; thirdly, the dip they all have indicates a higher source of outflow than the present altitude of the range could give. They are just what they would be if the places they now occupy had once been the excavated valleys of streams of a higher level than our present ones, into which great lava streams flowed, displacing their waters, and thus transferring their eroding power from old ravines to the

softer sediments around them, till the ravine full of lava became a mountain, and its former banks deeper excavations. These transverse lines of hills as seen from a point fifty or sixty miles away show a fine series of accordant lines in perspective, very suggestive of similarity of origin.

At the close of the period, in the geology of the Cascade region, represented by the facts mentioned: First, there existed the main range, here running north and south, and at a much higher altitude than the present; second, a series of offshoots from the range less in altitude than the range itself; and third, a series of deep and extensive interspaces excavated in the older softer sediments, in relation to which these basaltic offshoots became future partitions.

Now one of the largest of these offshoots, situated between Mt. Hood and Mt. Adams, is the Klickitat Mountain, which breaks the continuity of all eruptions after the commencement of the Pliocene or thereabouts.

As to the history of the deeply excavated interspaces, we may take the one nearly east of Mt. Hood. The Des Chutes Hill, one of these offshoots already described, is its northern barrier, and we may make it our standard of record. That this excavation was once 2,000 feet deeper than it is now is proved by the two facts that, first, the Des Chutes River has cut its channel through its present filling of basalt without reaching the bottom, and secondly, that this great thickness of rock lies in undisturbed and unbroken level. Twenty-six to thirty distinct outflows may be counted in the section, at the crossing of the Des Chuttes River. This later basalt is dark in color, dense in structure, and easily distinguished from the basalt of the neighboring hill, which has a brown color and is lighter. These later outflows filled up this vast excavation, then spread eastward and northward till they reached the outlying elevations of the foothills of the Blue Mountains. A well defined belt of sedimentary rock marks the strictly eastern limit of this outflow along the line of Antelope Valley and the John Day River. The nearest centers of eruptive outflow, other than those of the Cascade Range here, would be from the western spurs of the Blue Mountains. The largest of these was an eruption from the neighborhood of Camp Watson. It flowed into what seems to have been the old meandering valley of the John Day River. It appears to have filled up the valley and set the waters to excavating a new one for themselves. This old valley full of basalt is now a mountain 1,200 to 1,500 feet above the plane. The mold in which its mass was cooled has long since been washed or quietly worn away. This Blue Mountain basalt can easily be distinguished from that of the Cascades. It is filled with granulations of a dark green pyroxene that gives its weathered surfaces a pustulated appearance.

The undisturbed basalts that have filled up those vast excavations constitute a *second* series of operations in the region.

The diminished eruptions of later times make another group of facts, and in the respective fields of Mt. Hood and Mt. Adams

they differ widely. It is as if the eruptions from Mt. Adams had ceased in times of strong currents of lava, while those of Mt. Hood continued till recent times, with less and less of dense materials, and a vast increase in showers of ashes, and outflows of volcanic mud.

The limited amount of examination I have myself given the summit line of the Cascade Range hardly entitles me to state how far the interval between Mt. Hood and Mt. Shasta is covered with eruptive rocks. But if I should judge from the materials brought down in the beds of its streams, and the rocks I have gathered at points where I have crossed the summit, I should say nearly the whole. This answer will not seem so improbable if we remember that our present snow peaks, Hood, Jefferson, The Sisters, Dimond, Scott and Pitt, are only a few of the volcanic vents between Hood and Shasta. These named only mark recent vents, and not even half of these. Many older vents have been covered up.

Two years ago I felt intensely interested in the examination of one of the more recent deposits of the Cascade Range, a short description of which I will add here. This deposit was the result of an immense shower of volcanic ashes. The point at which I crossed it is perhaps midway between Hood and Shasta. Of course these showers of ashes would drift eastward of the summit, for the prevailing winds there are westerly. We encountered them six or eight miles west of the summit. The volcanic ashes were evenly laid over the whole surface, like a covering of snow. East of the summit there was a marked increase in its quantity, so much so, that the sharp features of the older surface ceased to show themselves through it. We traveled over it for a distance of fifty or sixty miles, noticing that as we receded, from the Cascade Mountains, its materials were finer and its bulk less.

Eastward from Mt. Rainier this volcanic ash is everywhere mixed in large quantity with the Pliocene deposits of the Yakima Valley. Around Mt. Adams it is almost entirely absent. It abounds again eastward of Mt. Hood. Former lake widenings of the Columbia around The Dalles show this material stratified, and containing fine impressions of late Tertiary leaves, although deposited 200 feet above present waters. The amount of this volcanic ash, upon the eastern slope of the Cascade Mountains, is enormous, and helps conceal from the observer the rocks below. It has in it cementing material, so that a fall of rain upon it seems to have been sufficient to prevent its subsequent drifting.

2. *Bulletin of the U. S. Geological and Geographical Survey of the Territories* (under F. V. HAYDEN, as Geologist-in-charge.) Vol. V, No. 2. 180 pp. 8vo.—This new number of the Bulletin contains the following papers: on the Coatis, by J. A. ALLEN; on the present state of *Passer domesticus* in America, and Second Installment of American Ornithological Bibliography, by Dr. E. COUES, U. S. A.; on the Laramie Group of Western Wyoming and the adjacent regions, by A. C. PEALE; on Litho-

phane and new Noctuidæ, by A. R. GROTE; on certain Carboniferous fossils from Colorado, Arizona, Idaho, Utah and Wyoming, and Cretaceous corals from Colorado, together with descriptions of new forms, by C. A. WHITE; on the so-called Two-ocean pass (Plates 3 and 4), by F. V. HAYDEN; on the extinct species of Rhinoceratidæ of N. America and their allies, by E. D. COPE.

Mr. White here illustrates anew the fact that in the Western Territories the Subcarboniferous, Carboniferous and Permian, making together a series 4,000 or 5,000 feet thick, have no distinctive fossils, but instead, a commingling of the species elsewhere characterizing them; and only occasionally do new species in the lower beds point to a Subcarbonaceous age. It is also true, as a rule, that the Devonian and Upper Silurian are absent in all that great region;" and when all evidence of the presence of the Subcarboniferous fails, it is probable that this division is likewise "absent and from one and the same cause or from similar causes." As to the Permian, its *time* is probably represented by the upper strata, but no Permian fossils occur in it that do not also occur in the great mass of Carboniferous strata beneath. So far as invertebrate fossils are concerned, there is great uniformity throughout; and the prevailing characteristics as to fauna are those of the Coal-measures and especially the Upper Coal-measures of the Mississippi basin.

3. *On Stromatopora*, by H. J. CARTER (Ann. Mag. Nat. Hist., V, iv, 253, 1879.)—Mr. Carter, in this third article on Stromatopora, points out the close relation of these corals in structure to the coralla of Hydractinia and Millepora, and thus sustains the Hydroid affinities of the group. The paper is illustrated by a plate representing sections.

4. *Note on the Section by Mr. T. Nelson Dale on page* 293 *of this volume;* by Dr. S. T. BARRETT. (Communication dated Port Jervis, N. Y., Oct. 8, 1879.)—In the section by Mr. Dale, No. 5 is Hall's *Stromatopora Limestone*, and is the same as the *Favosite Limestone*, No. 2 (five feet thick), of my paper in vol. xiii, May, 1877, of your Journal. The name Favosite limestone is a synonym for Hall's Stromatopora limestone, and has long been dropped by me. No. 1, "Encrinal limestone," of the same paper, is undoubtedly the equivalent, or, more properly speaking, the continuation of Hall's Coralline limestone, which I think I have made out to be the equivalent of the Niagara limestone; at least, Whitfield recognized in it, at Nearpass Quarry, *Halysites agglomeratus*, *Favosites pyriformis*, *Cladopora seriata*, *Cyathophyllum Shumardi*, and *Rhynchonella pisa*, along with several Coralline limestone species. See this Journal, vol. xv, 1878.

5. *Geological Atlas of the State of Ohio.* Prepared by J. S. NEWBERRY, Chief Geologist, and E. B. ANDREWS, E. ORTON, M. C. READ, G. K. GILBERT, N. H. WINCHELL, F. C. HILL, Assistant Geologists. Published by authority of the Legislature of Ohio. 1879.—This atlas, published as embodying the results of the recent Geological Survey, is in six large sheets, and presents the distribution of the formations in colors. It is a very handsome

map in its style of publication, and of great interest geologically. Like the Wisconsin map and some other recent geological atlases, it is very large, much larger than the amount of detail upon it made necessary; and, therefore, those having to consult it might well say, too large. Still the science of the land is greatly indebted to the liberality of the State of Ohio, and to its geologists, for this and all the publications of the Survey.

Some points in the details of the part of the map relating to the section of the State under the charge of Professor E. B. Andrews are not in accordance with his conclusions; and since he had no part personally, as he states, in the preparation of the map, his proposed corrections, recently received for this Journal, are here annexed.

"(1.) The Lower Carboniferous limestone– the Maxville limestone of my reports—is represented on the map as having a continuous outcrop, forming, with but a single short break, a continuous belt more than four hundred miles long, around the sinuous margin of the Coal Measures. In my investigations in this district, where I have long lived, I have found the Lower Carboniferous limestone only in the few localities mentioned in the Reports; and always in limited patches. The limestone belt of the map crosses the paths of Professor Orton in Pike County, Professor M. C. Read in Licking County, and Professor Stevenson in Muskingum, but none of these field-workers saw it, and their detailed geological sections give no hint of it. (2.) The Conglomerate at the base of the Coal Measures reported by Professor Orton in Pike County, and by myself in Jackson County, is omitted from the map. (3.) According to the map, the Waverly rocks, for a considerable distance, rest upon the Silurian rocks of the Cincinnati uplift without any intervening Devonian Black shale—the Huron shale of Dr. Newberry. This is not far from the eastern line of Adams County. My report for 1869, and the preliminary map give the belt of Black shale in its proper location, for 'it is finely exposed,' to quote from the report, 'in the Ohio River hills in the neighborhood of Rockville, Adams County, and in nearly all the hills which range to the north.' The final map represents the existence of the Black shale at Portsmouth and in the valley of the Scioto River above, where my searches only revealed Waverly rocks; but if there, the shale, rising to the westward, passes over a hilly mass of Waverly sandstone, and according to the map never comes out in any western outcrop."

6. *Geological Survey of Canada: Mesozoic Fossils*, Volume I, Part ii, *on the Fossils of the Cretaceous Rocks of Vancouver and Adjacent Islands in the Strait of Georgia;* by J. F. Whiteaves, F.G.S., Palæontologist to the Survey. 100 pp. 8vo, with 10 lithographic plates. Montreal, 1879.—The Cretaceous fossils are from the southeastern part of Vancouver Island, and pertain to two Coal-fields, the Comox and the Nanaimo. In the former, the thickness of the whole series is 4,912 feet, and that of the productive Coal-measures, 739½ feet; while in the latter, the whole

thickness is 5,266 feet, and that of the productive measures, 1,316 feet.

7. *On the Structure and Affinities of the Tabulate Corals of the Palæozoic Period, with critical descriptions of Illustrative Species;* by H. ALLEYNE NICHOLSON, Prof. Nat. History, Univ. St. Andrews. 338 pp. 8vo, with 15 plates. Edinburgh and London. 1879. (William Blackwood & Sons.)—Professor Nicholson has had opportunities in America as well as in his own land for the study of fossil corals, and has devoted much of his time for several years to the subject. The present work is the fruit of a large amount of careful study with the aid of microscopic sections, and many interesting results are brought out, as is exhibited on the several lithographic plates. On account of the abundance in this country of the corals treated of, the critical character of the work, and the comparisons made of American and European species or varieties, the work has special interest for both hemispheres. He states, as the general result of his investigations, that his labors corroborate the views of Verrill and Landström as to the necessity of abolishing the "Tabulata" as a separate division, and lead to the conclusion that under this old name there are included at least twelve distinct groups of corals.

8. *The Journal of the Cincinnati Society of Natural History*, vol. ii, No. 1, April, 1879.—Contains: Remarks on the genus *Poterocrinus*, by A. G. WETHERBY; Descriptions of new species of fossils from the Lower Silurian about Cincinnati, by E. O. ULRICH; Remarks on the Kaskaskia Group and descriptions of new species of fossils from Pulaski Co., Ky., by S. A. MILLER; Catalogue of plants growing in the vicinity of Cincinnati, by J. F. JAMES. It is illustrated by two Plates, 7 and 8; and the first species illustrated on plate 7 is the remarkable Crustacean, *Enoploura balanoides*, named by Meek, but first rightly understood and described by Mr. Wetherby. The price of the number is only 60 cents; of the volume $2.00.

9. *On the Old Red Sandstone of Western Europe*, by ARCHIBALD GEIKIE, F.R.S., Director of H. M. Geological Survey of Scotland, etc. Part I, 108 pp. 4to. From vol. xxviii, Trans. Roy. Soc. Edinb., 1878.—This memoir contains a general review of the facts connected with the "Old Red Sandstone," largely from personal investigations by the author, and a discussion of the changes in the physical geography of Western Europe which took place between the close of the Upper Silurian and the commencement of the Carboniferous period. It is illustrated by maps and sections.

10. *Outlines of Field Geology*, by ARCHIBALD GEIKIE. 216 pp. 12mo. London, 1879. (Macmillan & Co.)—This volume is intended for the guidance of the learner in field geology, and will be found a convenient manual. Professor Geikie's own labors in the field enable him to give instruction of much value on all points connected with the subject. Some will wish that it were more extended.

11. *Reports and Awards, Group I, International Exhibition*, 1876, edited by Francis A. Walker, Chief of the Bureau of

Awards. 486 pp. 8vo. Philadelphia, 1878. (J. B. Lippincott & Co.).—Group I was that including ores and mineral products, building stones, marbles and other useful and ornamental stones; also implements and machinery used in connection with the same, and various statistics relating to them. The volume contains reports by J. S. Newberry, W. S. Keyes, J. Lowthian Bell, T. Sterry Hunt, Frederick Prime, Jr., A. L. Holley, J. M. Safford, John Fritz, M. Addy, G. C. Broadhead, E. Althaus, L. Simonin and others; and in them there is a large amount of valuable information.

12. *Mémoire sur la Structure et la composition Minéralogique du Coticule*, par A. RENARD, S. J., Conservateur au Musée Royal d'Histoire Naturelle de Belgique. 44 pp. 4to. Brussels, 1877. (Mèm. Cour. Acad. Roy. Sci., Belgique, vol. xli.)—The author of this memoir proves by his investigations, that the fine yellowish whetstone, making the best of hones for razors, which is quarried at Salm-Château, Lierneux, Sart, Bihain and Recht, in Belgium, consists of massive manganesian garnet. It occurs in beds four to forty inches thick, in a slate, as a part of the slate formation. The characters of the beds are described in detail in the memoir. The composition of the whetstone of Recht, according to Dr. von der Mark (1) and M. Pufal (2), is as follows:

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	
1.	48·73	*tr.*	19·38	2·42	----	21·71	----	0·28	1·57	3·51	loss 2·40, F tr=99·88
2.	46·52	1·17	23·54	1·05	0·71	17·54	1·13	0·80	0·30	2·69	H_2O 3·28, CO_2 0·04, P_2O_5 0·16, S 0·18, organic matter 0·02=99·13

The slate, which is feebly metamorphic, is a damourite slate or schist; and the potash of the analyses is attributed to the presence of this mica in the whetstone. In microscopic sections the rock appears to consist of very minute granules—more than 100,000 in a millimeter-cube, and they show sometimes the form of the rhombohedron. In view of the form and the composition the conclusion is reached that the whetstone is a compact manganesian garnet or spessartine. This is sustained also by the specific gravity, which is 3·22, according to M. Pufal.

The occurrence of garnet in the "phyllade oligistifère" of Recht, an associated rock, was previously recognized by Zirkel.

M. Renard examined whetstones of other localities without finding a similar constitution; among them, the whetstone of Arkansas, which proved to be wholly quartzose, as had been shown by the analysis of Owen. The memoir is illustrated by a colored plate of microscopic sections.

13. *Report on the Minerals of some of the Apatite-bearing Veins of Ottawa County, Quebec, with notes on miscellaneous Rocks and Minerals* (1878); by B. J. HARRINGTON, Ph.D. 52 pp. 8vo. Montreal, 1879. (Geol. Survey of Canada).—Dr. Harrington describes the apatite deposits of Ottawa County as occurring most commonly in connection with rocks, which consist almost exclusively of pyroxene, though quartz and orthoclase

are often present, as also mica and minute garnets. When the pyroxene is the principal mineral the rock shows little trace of bedding, but is often much jointed and sometimes has the appearance of massive eruptive rock. Other rocks of the same phosphate region are gneisses, quartzites, and crystalline limestones. The apatite occurs in many cases in connection with pyroxene in what are regarded as true fissure veins. These veins have sometimes a banded structure, but in general are characterized by a want of regularity; the apatite crystals often show proof of having been broken and re-cemented. At some localities the apatite is chiefly in crystals, often of great size, "a foot or more in diameter and several feet in length, and weighing hundreds of pounds." The edges of the crystals are often rounded. At other localities, on the other hand, it is almost wholly massive, varying from compact or crypto-crystalline to coarse-granular; a friable saccharoidal variety is common. One mass of a sea-green variety is described which "as exposed measured nearly twenty feet across, and in the whole thickness was apparently free from other minerals with the exception of a few crystals of pyroxene and mica." The color of the mineral varies through many shades of green to sky-blue, red, brown, yellow and white. The specific gravity of a dark-green glassy crystal from the Grant Mine in Buckingham was found to be 3·2115.

A list of thirty species occurring in the apatite-veins is given, some of the most important of which are: calcite, quartz, pyroxene, hornblende, phlogopite, garnet, black tourmaline, titanite, zircon, orthoclase, scapolite. Of the associated minerals the most abundant is pyroxene, the commonest variety being an aluminous sahlite, but a light-colored variety is also common. An analysis of a blackish-green crystal afforded:—

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	ign.
G.=3·385	51·28	2·82	1·32	9·16	0·33	23·34	11·61	0·17=100·03

Other varieties also occur, sometimes in crystals of large dimensions.

The pyroxene is often partially or wholly altered to uralite. The change appears to have begun at the surface of the crystal and gradually extended inward; at the surface the hornblende prisms are mostly parallel to the vertical axis, within they run in all directions and are sometimes in radiating groups. One crystal had a center of glassy pyroxene (A), surrounded by a dull pale material (B), and this by an aggregation of hornblende (uralite) prisms (C). Analyses of these three portions afforded:—

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	ign.
A.	50·87	4·57	0·97	1·96	0·15	24·44	15·37	0·50	0·22	1·44=100·49
B.	50·90	4·82	1·74	1·36	0·15	24·39	15·27	0·15	0·08	1·20=100·06
C.	52·82	3·21	2·07	2·71	0 28	15·39	19·04	0·69	0·90	2·40= 99·51

The specific gravity was for A=3·181, for B=3·205, and for C=3·003. The change in composition from A to C is seen to consist principally in the loss of lime and gain in magnesia, though there is also a loss of alumina and slight gain in alkalies.

Dr. Harrrington also discusses the relations of the phosphate

region of Ottawa County to the Apatite-bearing veins of Norway described by Brögger and Reusch (ZS. G. Ges., xxvii, 646, 1875). There is a general similarity in the associated minerals and in other respects, but the apatite in Norway is described as occurring in an eruptive rock (gabbro), the crystals having been rounded by partial fusion. The latter part of Dr. Harrington's Report contains descriptions and analyses of a manganiferous calcite, of chrysolite, of some diorites near Montreal, and other points of interest. E. S. D.

14. *Die Pseudomorphosen des Mineralreichs; vierter Nachtrag* von Dr. J. Reinhard Blum. 212 pp. 8vo. 1879. Heidelberg. (Carl Winter).—Sixteen years have passed since the preceding appendix (the third) to his important work on the Mineral Pseudomorphs was published by Professor Blum. The many friends of the veteran author will rejoice that his life and strength have been spared so long, and that he has been able to add another important contribution to a branch of mineralogical science which owes its distinct existence to his labors. The general recognition of interest attached to the study of the changes in the chemical composition of minerals is shown by the large number of published researches which have had this as their subject; the number of pseudomorphs described in the original work (1843) was 164, and this has since been increased to 436. The present volume contains all the cases which have been described since the appearance of the last appendix. The 200 pages devoted to them is a proof of their number and the care with which the author discusses them. E. S. D.

III. Botany and Zoology.

1. *Electrical Currents in Plants.*—In a notice of the action of *Dionæa* and other irritable plants, published soon after the popular exhibition of the electrical phenomena attending the movement, said to be similar to those attending the contraction of a muscle, we threw out the suggestion that these remarkable phenomena were not unlikely to be explained away. The suggestion was founded on some investigations and trials made in the botanical laboratory of Harvard University by Professors Goodale and Trowbridge, which were never published, there being an intention to follow them up later. It appears that Kunkel has taken up this investigation and reached the same result, in the laboratory at Würzburg. His paper,* as abstracted by Micheli in Arch. Sci. Phys. and Nat. for Sept., 1879, announces that he does not admit the existence of any electrical tension in the intact tissues of the plants in question, but he concludes that the currents developed upon spontaneous movement, and similarly upon artificial curvature, are due to movements of the liquid in the cells caused by mere contact with the electrodes, or by either active or passive movements of the organs. A. G.

* Ueber electromotorische Wirkungen an unverletzen lebenden Pflanztheilen.

2. *Adnotationes de Spiræaceis*, auct. C. J. Maximowicz. (Seorsim impressæ ex Actis Horti Petropolitani, tom. vi.) Petropoli, 1879, pp. i–xii, and 105–261, 8vo.—This is one of the most considerable botanical papers of the time. It will require to be carefully weighed before its conclusions are either rejected or adopted. Dr. Maximowicz separates the *Pomaceæ* from the *Rosaceæ* (these including the *Amygdaleæ* or *Pruneæ*), and, reducing the value of adhesion of calyx-tube with the gynœcium (to which we cannot in principle object), refers his *Spiræaceæ* to the order *Pomaceæ*, and divides the order into two families, *Pomaceæ* proper, with a succulent-fleshy calyx-tube which is usually connate with the carpels, and *Spiræaceæ* with an herbaceous calyx-tube, free from the dehiscent carpels. The order thus constituted is regarded as intermediate between *Rosaceæ* and *Saxifragaceæ*. The Linnæan *Spiræa*, which must be allowed to be composite and which included four Tournefortian genera, is distributed among the tribes of the first two orders.

The *Spiræaceæ* are divided into several tribes: the *Spiræeæ*, with carpels when isomerous with the sepals alternate with them, containing *Aruncus*, *Eriogynia* (preferred to *Lutkea*, though possibly, and we suppose without much doubt, not quite so old), *Spiræa* (of the sections *Petrophytum*, *Chamædryon*, and *Spiraria*), and *Sibiræa* (*S. lævigata* L.); these have little or no albumen and thin coat to the seed: *Neillieæ*, differing in having a smooth and stony seed-coat and very distinct albumen (*Physocarpus*, *Neillia*, *Stephanandra*, under which arrangement the separation of the first two seems most proper): *Gillenieæ*, with the carpels opposite the sepals when of the same number, otherwise nearly with the characters of the preceding; this includes *Sorbaria* (Lindley's *Schizonotus*), *Chamæbatiaria* (horrid name for a genus, taken from the sectional name given by Professor Porter to *Spiræa Millefolium* Torr.), *Spiræanthus*, of a single Siberian species, and *Gillenia;* finally the *Quillaieæ*, with winged seeds, the first genus of which is *Exochorda*. To *Rosaceæ*, as here limited, Maximowicz refers *Filipendula* (including *Spiræa filipendula*, *Ulmaria lobata*, and the like), excluded from the *Spiræeæ* and included in the *Sanguisorbeæ* on account of their indehiscent and one-seeded (biovulate) carpels; and *Holodiscus* of Koch (composed of *Spiræa discolor* and the Andine *S. argentea*), which is referred to the *Potentilleæ*, along with *Cercocarpus*, *Cowania*, and *Fallugia*, with the remark that its biovulate achenia ally it to the *Rubeæ*. Of *Rubus* it is said that the seeds are distinctly albuminous; and *Kerria*, *Neviusia*, and *Rhodotypus* are placed among the *Rubeæ*. A. G.

3. Boissier, *Flora Orientalis*, vol. iv, pp. 1276, 8vo.—This Oriental Flora, as is well known, covers the ground from Greece to Egypt, and to the boundaries of India and of Asiatic Russia. This fourth volume, completed early in 1879 by the publication of the second fasciculus (of almost a thousand pages), contains the *Corollifloræ* and the *Monochlamydeæ*, in other terms the Gamopetalous and Apetalous Exogens. We may therefore expect that

the indefatigable author will ere long complete this laborious and noble work. These fifteen or twenty years will then be distinguished by the production of the *Flora Australiensis* and the *Flora Orientalis.* Would that the Flora of North America were added to the number. A. G.

4. *Sulla Diffusione dei Liquide Colorati nei Fiori ;* by Professor P. A. SACCARDO.—The writer gives an account of his experiments in immersing cuttings of flowering plants in different coloring fluids, and concludes by saying that aniline-green is especially favorable for staining not only the vessels but the parenchyma of flowers. The paper is followed by a sheet on which actual specimens of stained petals serve as illustrations, with a pleasing effect. W. G. F.

5. *Neue Beobachtungen über Zellbildung und Zelltheilung;* by Professor ED. STRASBURGER.—Nos. 17 and 18 of the Botanische Zeitung contain an important article by Strasburger. It had generally been admitted by botanists, including Strasburger himself, that the endosperm was formed in the embryo-sack by free-cell formation. Strasburger now says that this is not true, and that there is no formation of free nuclei in the embryo-sack ; he having in previous papers shown that the embryonal vesicle and antipodes do not arise by a free-cell formation. As in the case of the two last named structures, the endosperm-cells are formed by a division of the nucleus of the embryo-sack. *Myosurus minimus* is especially adapted for the study of the subject, owing to the elongated receptacle. Strasburger also states that in the *Ascomycetes* the spore-formation is not preceded by a dissolving of the nucleus of the ascus followed by the formation of free nuclei, but that the original nucleus divides to form the nucleus of each spore. He makes the sweeping assertion that a free formation of nuclei as the initial stage of cell-formation cannot be assumed (in plants), unless we conceive such to be the case in the mother cells of the spores in *Anthoceros* and in those of the macrospores of *Isoëtes,* in which cases observation is obscured by the presence of granular accumulations in the cells. He does not deny, however, that free nuclei may be formed in some instances, but only that it does not accompany cell-formation. In *Spirogyra,* for instance, the spore has at first no nucleus but one is formed at the time of germination. The same is true of the swarm-spores of *Ulothrix.*

The last part of the paper treats of the different arrangements of nuclear plates and nuclear threads, as a comprehensive distinction between the division of animal and vegetable cells in the formation of what Strasburger calls the cell-plate in plants. This is dependent upon the presence of a cellulose membrane in plants. It may be objected, however, that no cellulose membrane can be detected in many plant-cells. W. G. F.

6. ARNOLD ARBORETUM.—*Prof. Charles S. Sargent* is appointed Professor of Arboriculture in Harvard University, along with the directorship of the Arnold Arboretum at the Bussey Institution. He now devotes himself entirely to the arboretum, resigning the

charge of the Botanic Garden at Cambridge, which is assumed by Professor Goodale.

7. Prof. J. G. AGARDH has resigned the chair of Botany at the University of Lund. *Dr. F. W. C. Areschoug* has been appointed his successor.

8. P. VAN TIEGHEM is appointed Professor of Vegetable Anatomy and Physiology at the Jardin des Plants, Paris, in the chair vacated by the death of Brongniart some years ago.

9. Dr. ODOARDO BECCARI succeeds to the late Prof. Parlatore as Professor of Botany and Director of the Gardens at Florence.

10. *Die Spongien des Meerbusen von Mexico*, von OSCAR SCHMIDT. 4to, 1st Heft, with four plates. Jena, 1879.—This memoir relates to sponges collected by the dredging expedition of the steamer Blake, under the supervision of Alexander Agassiz. The excellent plates illustrate the forms and spicula of many species.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Catalogue of Scientific Serials*, from 1633 to 1876, by SAMUEL H. SCUDDER. 358 pp. 8vo. Cambridge, Library of Harvard University, 1879.—This catalogue embraces the Transactions and Bulletins or Proceedings of Learned Societies in the Natural, Physical and Mathematical sciences of all countries, as well as independent journals. It has been prepared, under the auspices of the Harvard College Library, by Mr. Scudder, assistant Librarian; and it is a result of a vast amount of labor and great care. All persons interested in the progress of science will find it an invaluable companion. The titles are arranged alphabetically under the heads of each of the States or Countries from which they were issued, and, in addition, there are Indexes of titles and of places of publication. Harvard Library has met the expense of publication, with the expectation that the demand for the volume will refund the outlay, and with the promise that if so far remunerated, this shall be the beginning of a series of "works such as may be properly undertaken by a public Library, and do not offer inducement for commercial speculation;" and it will be greatly for the benefit of learning in the land, that in this there should be no disappointment.

2. *A Sketch of Dickinson College*, Carlisle, Pennsylvania; by CHARLES F. HIMES, Ph.D., Professor of Natural Science. 156 pp. 12mo, illustrated by engravings, and by photographs executed in the Laboratory. Harrisburg, 1879.—*The History of Dickinson College*, has a general interest because of the connection with its scientific department, the second year after its establishment, in 1811, of Thomas Cooper, the friend, and companion over the sea, of Priestley—a man of wide range of learning, of great chemical knowledge for his time, and of strong opinions on all subjects. Prof. Himes's "Sketch," contains, among its photographic plates, one with figures of the air-gun and burning glass which, along

with a telescope, Dr. Cooper purchased of Priestley for the college, by authority of its Board of Trustees, and which are now among its physical apparatus. It appears further from the sketch that it was while in this position that Dr. Cooper revived the "Emporium of Arts and Sciences," one of the earliest of American Scientific Journals, and gave it "a high scientific character," and issued also an edition of Accum's Chemistry in two volumes. Thus the scientific department of Dickinson was one of the earliest established in the country, and behind no other in the learning and ability of its chief instructor. The Journal, a bi-monthly of 150 pages, came to an end in 1814—the long delay of the final volume being explained by the fact of "the printers serving their country as volunteers." Dr. Cooper left his chair in 1815, and became afterward President of South Carolina College. Prof. Baird, a graduate of Dickinson College, now Secretary of the Smithsonian Institution, was made its Professor of Natural History in 1848, and held the office until 1850, when his connection with the Smithsonian Institution began under Professor Henry.

3. *Ephemeris of the Satellites of Mars for October and November*, 1879.—The ephemeris on pages 317, 318 of this volume, was prepared for the Journal by Henry S. Pritchett, Assistant Astronomer in the United States Naval Observatory at Washington.

4. *Scientific Lectures;* by Sir JOHN LUBBOCK, Bart., Vice President of the Royal Society, etc. 188 pp. 8vo. London, 1879. (Macmillan & Co.).—This volume contains six lectures by Sir John Lubbock: on Flowers and Insects, on Plants and Insects, on the Habits of Ants, Introduction to the Study of Prehistoric Archæology, and an Address to the Wiltshire Archæological and Natural History Society. They are in part the result of original research; and although, as the Preface says, "the little book does not contain anything new to those who have specially studied the parts of science with which it deals," many of the facts are among the most remarkable in science, and make instructive and attractive reading for all inquiring minds. Further, they are well calculated to cultivate an inquiring spirit in the mind of those who have thought themselves indifferent to the study of nature.

5. *Shell Mounds of Omori*, by EDWARD S. MORSE, Prof. Zool. Univ. Tokio, Japan. Mem. Univ. Tokio, vol. i, part 1, 1879. 36 pp. large 8vo, with 18 plates.—Professor Morse gives evidence that the mound-builders were cannibals either from an emergency or by preference. The implements obtained are made of stone, horn, bone and pottery, but there are no arrow-heads or spear-points of flint or other material, and few of the relics are of stone.

Report of Work of the Agricultural Experiment Station, Middletown, Conn., 1877–8. 174 pp. 8vo. Hartford, 1879.